SCIENCE

VOL. 74 FRIDAY, OCTOBER 9, 1931 No. 1919

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SCIENCE: A Weekly Journal devoted to the Advancement of Science, edited by J. MCKEEN CATTELL and published every Friday by

THE SCIENCE PRESS

New York City: Grand Central Terminal

Lancaster, Pa. Garrison, N. Y.

Annual Subscription, $6.00 Single Copies, 15 Cts.

SCIENCE is the official organ of the American Association for the Advancement of Science. Information regarding membership in the Association may be secured from the office of the permanent secretary, in the Smithsonian Institution Building, Washington, D. C.

A HUNDRED YEARS OF EVOLUTION[1]

By Professor E. B. POULTON

HOPE PROFESSOR OF ZOOLOGY, UNIVERSITY OF OXFORD

THINKING over the subject of this address, I have been encouraged by a metaphor given me by Oliver Wendell Holmes at a delightful dinner of the Boston Saturday Club in January, 1894—"Memory in old age is a palimpsest with the records beneath standing out more clearly than those above." And, indeed, memories of my first British Association, at York in 1881, are clearer than those of many in later years. It was a great meeting, as befitted the fiftieth anniversary, and nearly every sectional president had been a president of the association. It also marked a turning-point in evolutionary controversy, being, I believe, the last meeting at which opposition was offered to evolution as apart from its motive cause or causes. From 1881 onwards the battles in this section have been over Lamarckism and natural selection and their factors, especially heredity; over the size of the steps and the rate of progress. Evolution itself has been generally accepted. It was different at York in 1881. Dr. Wright's indignation, when the reptilian affinities of *Archeopteryx* were explained in the geological section, was stirred by the hated doctrine which gave meaning and life to the demonstration. I well remember, too, how Professor O. C. Marsh, discussing one of the meetings in this section with a young and inexperienced naturalist, said that he had felt rather anxious about the way in which his paper on the Cretaceous toothed birds of America would be received by the president, Sir Richard Owen. His fears were, however, groundless, and all was well.

The difference between the controversies raised in the first and the second of these half-centuries of evolution reminds us that long before Darwin saw his way to an explanation of evolution he was satisfied that evolution was a fact; reminds us, too, that we are celebrating another great centenary, for he sailed in the *Beagle* on December 27, 1831, thus entering upon the five years' voyage which, in his own words, "was by far the most important event in my life, and

[1] Address of the president of Section D—Zoology, British Association for the Advancement of Science, London, September, 1931.

has determined my whole career"—the voyage which provided him with the evidence that evolution is a fact. The idea of natural selection as a motive cause did not come to him until October, 1838, just two years after his return.

The independent discovery and publication of the principle of natural selection by Dr. W. C. Wells[2] in 1818 and by Patrick Matthew in 1831 followed a very different course, for neither of these men realized the significance of the idea which had come to him. Wells wrote that he had ventured to expound it, "though at the hazard of its being thought rather fanciful than just," and Matthew half apologizes for the amount of space which has been taken from his main subject. He was, nevertheless, anxious to claim credit when, twenty-nine years later, the importance of the discovery was revealed to him in the *Gardener's Chronicle* reprint of the *Times* review of the "Origin," the review of which Huxley said, "I wrote it, I think, faster than I ever wrote anything in my life." It is interesting to speculate upon what might have happened if the author had called his book "Arboriculture and Naval Timber" instead of the more severely technical "Naval Timber and Arboriculture"; for, with the former title, the work might well have been consulted by Darwin who would have been led by the table of contents to discover its significance.

Robert Chambers' "Vestiges of the Natural History of Creation," which appeared in 1844, undoubtedly includes illuminating thoughts far in advance of the time. Thus, more than once, the author writes of organic life "pressing in" when suitable conditions arose, "so that no place which could support any form of organic being might be left for any length of time unoccupied," and he also speaks of withdrawals when the appropriate conditions pass away. Then, too, Anton Dohrn's "Functionswechsel" is foreshadowed in the conclusion that "organs, while preserving a resemblance, are often put to different uses. For example: the ribs become, in the serpent, organs of locomotion, and the snout is extended, in the elephant, into a prehensile instrument." And, contrasted with this, the author points to the performance of the same functions by "organs essentially different," and then to the consideration of rudimentary structures and the recognition that "such curious features are most conspicuous in animals which form links between various classes." Of great interest, too, is the forcible rebuke administered to those who maintain that an animal origin for man is a degrading thought.

[2] Wells, like Matthew and Chambers, was a Scotsman. He was born (May 1757) of Scottish parents in Charlestown, South Carolina. In the troubled times preceding the Declaration of Independence his father, to quote his own words, "obliged me to wear a tartan coat, and a blue Scotch bonnet, hoping by these means to make me consider myself a Scotchman. The persecution I hence suffered produced this effect completely."

It was a credulous age and we need not be astonished at the author's belief in a spontaneous, or as he preferred to call it, "aboriginal," generation of clover in waste moss ground treated with lime, and his opinion that an explanation based on the presence of dormant or transported seed was "extremely unsatisfactory"; or, again, his acceptance of the hypothesis, held by some authorities at the time, that parasitic entozoa were produced from "particles of organized matter" within the host, such a development being, he considered, "in no small degree favorable to the general doctrine of an organic creation by law." The authorship of the "Vestiges" was revealed in Alexander Ireland's introduction to the 12th edition, published in 1884, thirteen years after Chambers' death. The secrecy appears to have been mainly due to a rule, laid down in the Chambers' publishing business, that "debatable questions in politics and theology" should be avoided.

I have devoted some little time to the "Vestiges," which I think has hardly received its due, although Darwin fully acknowledged its importance in preparing many minds for a belief in evolution. We know, too, that the author warmly supported the Darwinian cause in the controversy which arose over the "Origin," and that it was his advocacy which rendered possible the great encounter at Oxford in 1860; for when Huxley told him that he did not mean to attend the meeting of the section on June 30—"did not see the good of giving up peace and quietness to be episcopally pounded," "Chambers broke into vehement remonstrances, and talked about my deserting them. So I said, 'Oh! if you are going to take it that way, I'll come and have my share of what is going on.'" And after the meeting, J. R. Green wrote to his college friend, Boyd Dawkins—"I was introduced to Robert Chambers the other day and heard him chuckle over the episcopal defeat."

Owing to the kindness of Lady Boyd Dawkins and Dr. Leonard Huxley, I am able to print a very interesting and hitherto unpublished letter in which Huxley confirmed the well-known description of the debate given by Green:

4 Marlborough Place,
Abbey Road, N.W.
June 11, 1883.

My dear Boyd Dawkins,

Many thanks for the extract from Green's letter. His account of the matter appears to me to be accurate in all essentials, though, of course, I can not be sure of the exact words that were used on either side.

It is curious that your letter should have reached me this morning, when in a couple of hours I shall start for Cambridge for the purpose of delivering the Rede Lecture on the subject of "Evolution." I should not have chosen this topic of my own mere motion. But I found that nothing else would satisfy the expectations of Cam-

bridge! Truly "the whirligig of time brings its revenges."

I am,

Yours very sincerely,

T. H. HUXLEY.

Robert Chambers' work appears to have provided the stimulus which led to the preparation of an interesting and surprising manuscript[3] by the younger J. Searles Wood. It was found by my friend, Sir Sidney Harmer, among his father's papers, and bears a note, dated 1866 and signed J.S.W., Jr., stating that it "was written about 1848 or 1849 and the pencil alterations made at the time." The paper, however, bearing a water-mark of 1850, supplies a rather comforting correction, for the author was not born until 1830, and at eighteen or nineteen must have been a very precocious youth to have written such a manuscript. Searles Wood, who was a great admirer of Lamarck, was evidently stirred by the immense success of the "Vestiges" and doubtless especially by the statement that the hypothesis of the French naturalist "deservedly incurred much ridicule, although it contained a glimmer of truth." The manuscript is, however, far more than a defense of Lamarck: it contains powerful arguments in favor of evolution, based upon the very grounds which convinced Darwin himself—the "wonderful relationship in the same continent between the dead and the living," and between island species, especially in the Galapagos, and those of the nearest continental area. It will be remembered that Darwin's pocket-book for 1837, referring to this very evidence, contains the words, "These facts (especially latter) origin of all my views." At the side of a page on which the argument on island life is developed, Searles Wood had noted—"When I wrote this, Mr. Darwin had not broached his hypothesis and was not known to be any other than a believer in creation. J.S.W. Jr. 1866." Darwin's "Journal" was first published in 1839, the second edition in 1845, but I have not heard of any reader except Searles Wood who recognized, before the appearance of the Darwin-Wallace Essay and the "Origin," that organic evolution was an irresistible conclusion from the facts recorded by the author. Other important arguments, brought forward in the manuscript, will, I am sure, be read with the utmost interest when it appears in the Linnean proceedings.

A curiously interesting event in 1858, the year of the Darwin-Wallace Essay, was the appearance of "Omphalos," so well described, with the eager expectation and bitter disappointment of its author, in Sir Edmund Gosse's "Father and Son." It is unnecessary to repeat on this occasion the often told and never-to-be-forgotten story of the Joint Essay and the Linnean Society's celebration of its fiftieth anniversary, when Wallace protested in noble and inspiring words against the undue credit which he considered had been allotted to him for his share in the discovery of natural selection—a discovery brought to him, as it was brought to Darwin, by the reading of Malthus "On Population."

The effect of the Darwin-Wallace Essay upon Canon Tristram and the appearance, a few weeks before the "Origin," of his paper on the ornithology of the Sahara was brought before this section by Professor Newton at Manchester in 1887, and by the author himself at Nottingham in 1893. It is, however, desirable to emphasize its significance afresh in view of recent attempts to throw doubt on the value of concealing coloration in desert areas. Tristram was led to a belief in natural selection when he read the Essay in the light of a recent experience of many months in the Algerian Sahara, where he had observed that "the upper plumage of every bird, . . . and also the fur of all the small mammals, and the skin of all the Snakes and Lizards, is of one uniform isabelline or sand colour," and had come to realize the absolute necessity for the vast majority of the species to be thus concealed upon the uniform surface of the desert. Precisely the same necessity had been recognized in South Africa nearly half a century earlier by Burchell, when he observed the protective resemblance of a *Mesembryanthemum* and a grasshopper to pebbles, and the defensive value of thorns and acrid secretions in a bare dry country "where every juicy vegetable would soon be eaten up by the wild animals." Burchell's mention of plants with an "acrid or poisonous juice" suggests the meaning of the conspicuousness of the relatively few black, slow-moving insects which have been thought to throw doubt upon the whole theory of protective coloration in the desert. The problem is complex and the struggle for existence is waged in many ways, important among them being the physiological adaptations by which the imperative need for moisture is satisfied—a subject on which much light has been thrown by P. A. Buxton.

Coming now to the meetings of the British Association and of this section in the second half-century, we are naturally led to the discussion, "Are Acquired Characters Hereditary?" at Manchester in 1887, when Weismann, Ray Lankester, Hubrecht and many others spoke; and to the same subject at Newcastle in 1889 when Francis Galton and Fairfield Osborn, our welcome guest to-day, took part in the debate.

It was only natural that Weismann's conclusions should rouse intense opposition, for they undermined the foundations on which so much evolutionary theory had been erected. I remember Sir William Turner's

[3] Presented by Sir Sidney Harmer, F.R.S., to the Linnean Society of London. It is hoped that the manuscript will be published in the Proceedings of the Society when the rather difficult task of editing has been completed.

words at one of our meetings about this time—"Whoever believes that acquired characters are not transmitted looks upon life with a single eye"—not in the Biblical sense, but implying monocular vision; also Lawson Tait's dogmatic statement at a meeting of the Midland Institute at Oxford in 1890, that a believer in Weismann's conclusion "says that the sun shines black." One result of the new doctrine—the collapse of Herbert Spencer's "Synthetic Philosophy," so largely built upon Lamarckian principles—was especially distressing to those who remembered a beneficent power in teaching the world to think; remembered, too, what it had done for themselves in earlier years. But not all naturalists were startled and amazed when Weismann "awoke us from our dogmatic sleep." I well remember Ray Lankester's reply when I first mentioned the subject to him—"I believe Weismann is right. I have always doubted the statement that acquired characters are transmitted." And his two old Oxford friends, H. N. Moseley and Thiselton-Dyer, were also ready to follow Weismann from the first. Two sayings of Weismann may be recalled here—how the "Continuity of the Germplasm," the theory which first led him to doubt the accepted views on heredity, came to him when he discovered that "there was something which had to be carefully preserved" throughout the development of a hydrozoon, *viz.*, that unexpended portion of the parental germ-cell which will give rise to the germ-cells of the offspring. Shielded and "carefully preserved" as was this carrier of hereditary qualities, how improbable was the conclusion, that it would be effected by the happenings in distant parts of the organism, how doubly improbable the supposition that the effect would reproduce the result of these happenings in the offspring. All this is, of course, well known, but it is interesting to recall it as told by Weismann himself. His other remark was to the effect that if acquired characters could be transmitted, we should not be obliged to search for the evidence. It would have been obvious everywhere.

Although, as my friend and colleague, Professor Goodrich, has written—"these conclusions of Weismann . . . are the most important contribution to the science of evolution since the publication of Darwin's "Origin of Species,"[4] it was soon realized that the statement of the problem required revision and that Weismann's terms "Blastogenic" and "Somatogenic" were inaccurate; for the germinal or inherent characters are no less dependent on external causes than the somatic or acquired characters. This criticism was developed by Adam Sedgwick in his address to this section at Dover in 1899 and by Goodrich at Edinburgh in 1921; also, between these two addresses, by Archdall Reid. Furthermore, in the spring of 1890, when I was giving a course of university extension lectures on "Evolution and Heredity" at Gresham College, the same idea was expressed in an answer written by one of the students. I was very fortunate in my audience, which included Professor A. G. Tansley, F.R.S., Wilfrid Mark Webb and W. Platt Ball.[5] The last-named student, in one of his answers, wrote to the following effect, if I may trust a memory of over forty years—"Acquired characters are due to external causes acting upon inherent potentialities; inherent characters are due to inherent potentialities acted upon by external causes." The distinction, which seems at first sight difficult and confusing, is very clearly shown by a simple diagram given by Professor Goodrich,[6] who considers that the expression "acquired character" should be dropped. Its history is, however, so interesting—Erasmus Darwin (1794), Lamarck (1809), Prichard (1813)—and its use still so general that we may hope for its continuance, considering especially the vital importance in every-day life of the facts which it describes. It is difficult to imagine Johannsen's term—"phenotype"—replacing it in discussing the problems of education or crime.

In mentioning the name of the illustrious anthropologist, James Cowles Prichard, I may remind the section that the non-transmission of acquired characters was maintained by him in the second edition (1826) of his great work, "Researches into the Physical History of Mankind."[7] I have recently studied the first edition (1813) and find that the same conclusion was affirmed at this earlier date. Thus, on page 195, the author states, "the changes produced by external causes in the appearance or constitution of the individual, are temporary, and in general acquired characters are transient and have no influence on the progeny." Again, on page 232, arguing that age-long exposure to heat did not cause the dark color of tropical races, he continues "and this fact is only an instance of the prevalence of the general law, which has ordained that the offspring shall always be constructed according to the natural and primitive constitution of the parents and therefore shall inherit only their connate peculiarities and not any of their acquired qualities"—a very remarkable statement to find in a book published eighteen years before the first meeting of the British Association. I must also mention on this occasion the paper[8] contributed to

[4] "Living Organisms," Oxford, pp. 50, 51, 1924.

[5] Author of "The Effect of Use and Disuse," "Nature Series," London. The excellent term "Use-inheritance" to signify "the direct inheritance of the effects of use and disuse in kind," was suggested in this book.

[6] *Ibid.*, p. 54. See also p. 62, n. 1.

[7] *Science Progress*, April, 1897. Reprinted in *Essays on Evolution*, Oxford, 1908.

[8] *Abstract of a Comparative Review of Philological and Physical Researches as Applied to the History of*

the second meeting at Oxford in 1832, in which Prichard contends, in opposition to Cuvier, "that the various tribes of men are of one origin."

The rediscovery of Mendel's work—epoch-making although the birth of the epoch was long delayed—produced an immense effect on the papers and discussions in this section. Much of the controversy in the first and second decades of this century arose out of the belief that only large variations—or as they were called, "mutations," using an old word with a new meaning—are subject to Mendelian inheritance, and to the related belief that small variations are not inherited at all. But towards the end of this period the foundations of the controversy vanished, for as Professor H. S. Jennings[9] pointed out in 1917, the work of W. E. Castle and T. H. Morgan proved that the smallest characters are hereditary, so that "the objections raised by the mutationists to gradual change through selection are breaking down as a result of the thoroughness of the mutationists' own studies." To give a single illustration—between a red-eyed and a white-eyed fruit-fly (*Drosophila*) seven gradations of color intervene, each of them "heritable in the normal Mendelian manner." Furthermore, in the middle member of this series, "Bridges has found seven modifying factors, each of which alters its intensity and gives rise to a secondary grade of color. Now each [all] of these modifying factors are described 'specifically as mutations; as actual changes in the hereditary material.'" The author finally concludes that "Evolution, according to the typical Darwinian scheme, through the occurrence of many small variations and their guidance by natural selection, is perfectly consistent with what experimental and paleontological studies show us"; indeed, it appears to him to be "more consistent with the data than does any other theory," a conclusion confirmed by Dr. R. A. Fisher's recent work, "The Genetical Theory of Natural Selection." Mendelian heredity also provided an effective answer to a difficulty by which Darwin had been greatly troubled—the supposed "swamping effect of intercrossing" on which Fleeming Jenkin had written a powerful article.[10] Moreover, it can not be doubted that Mendelian research, by demonstrating the paramount importance of germinal qualities, played a great part in promoting the general acceptance of Weismann's teaching.

A mistaken belief prevailed in the early years of the Mendelian rediscovery that a new theory of evolution had been revealed to the world and that Darwinism had been abandoned. The true position was emphatically stated by Miss E. R. Saunders at the Cardiff Meeting in 1920—"Mendelism is a theory of heredity; it is not a theory of evolution."

I need not dwell upon the paleontological evidence for continuous evolution, as Professor Osborn is here and we shall soon have the pleasure of listening to one who can tell us of the conclusions to be inferred from the matchless record of past ages in the great museum of which he is the director.

The important subject of geographical races or subspecies will be discussed next Tuesday, and I will now only refer to the splendid work of the Tring Zoological Museum under the guidance of Lord Rothschild, Dr. Hartert and Dr. Jordan, and the conclusions published in their journal in 1903.[11] "Geographical varieties . . . represent various steps in the evolution of daughter-species"; and "whoever studies the distinctions of geographical varieties closely and extensively, will smile at the conception of the origin of species *per saltum*."

The age of the earth, as estimated by Lord Kelvin and Professor Tait, was one of Darwin's "sorest troubles." "I should rely much on pre-Silurian times," he wrote in 1871, "but then comes Sir W. Thomson, like an odious spectre." Lord Salisbury's treatment of this subject in his address at Oxford in 1894 will be remembered by many. Entirely accepting the fact that Darwin had "disposed of the doctrine of the immutability of species," he ridiculed the demands which evolution by natural selection makes upon the bank of time. "Of course if the mathematicians are right, the biologists can not have what they demand. If, for the purposes of their theory, organic life must have existed on the globe more than a hundred million years ago, it must, under the temperature then prevailing, have existed in a state of vapor. The jellyfish would have been dissipated in steam long before he had had a chance of displaying the advantageous variation which was to make him the ancestor of the human race." I venture to refer to this difficulty, although a difficulty no longer, because it provides a good illustration of the help which so often comes to us at these meetings, and also recalls a vigorous personality, our kindly treasurer for many years, Professor John Perry. Walking together on the Sunday of the Leeds Meeting in 1890 he explained to me the evidence on which Thomson and Tait had relied, and said that he believed the argument founded on the cooling of the earth to be sound. When, however, he heard Lord Salisbury's address four years later, and decided to re-examine the evidence, he soon discovered that an important consideration had been overlooked.

the Human Species. The abstract occupies fifteen pages of B.A. Reports, vol. i. (including the first two meetings).

[9] *Journ. Washington Acad. Sci.*, vol. vii, No. 10, p. 281, May 19, 1917; *American Naturalist*, vol. li., p. 301, May, 1917. The statements here reproduced are quoted from a brief summary of these two papers in *Proc. Ent. Soc. Lond.*, 1917, p. lxxxv.

[10] *North British Review*, June, 1867.

[11] *Nov. Zool.*, vol. x, p. 492, 1903.

With his kind help I chose this subject, together with the biological evidence for the age of the habitable globe, for my address at Liverpool in 1896. In the following year as we were traveling across Canada after the Toronto meeting and the chance of collecting insects for a few minutes at each station could not be resisted, Lord Kelvin said to his wife: "My dear, I think we must forgive Poulton for thinking that the earth is so very old when he works so hard in one day out of all the endless millions of years in which he believes!" A quarter of a century later "The Age of the Earth" was the subject of a joint discussion at Edinburgh, when the Thomson-Tait limitation of time was abandoned in consequence of researches on radio-activity.

We now come to biological criticisms of evolution by natural selection, especially those urged by my friend Sir John Farmer in his presidential address to the botanical section at Leicester in 1907,[12] and concisely restated in 1927.[13] In the latter publication the theory of evolution as it was held forty years ago, and, I may add, very nearly as it is held to-day, was described as "the notion that the basis of evolutionary change in living forms lay in the gradual summation of almost imperceptibly small variations, and that, in fact, specific change was attributable to selection and accumulation of these small variations as the result of environmental conditions." Except for the implied restriction of selection to "almost imperceptibly small variations," the statement appears to express fairly the opinion of many believers in natural selection at the centenary of the British Association. One main criticism of this belief was that it led to "the facile teleology, which, like a noxious weed, had overgrown the solid framework of evolutionary doctrine." But this was not a necessary nor, in my opinion, a common result of the evolutionary beliefs of those years. Let me give two examples of teleological interpretations offered forty years ago, interpretations which are anything but "noxious weeds," being extremely interesting in themselves and pointing directly to further researches and a further strengthening of the "solid framework."

On his return from a visit to Ceylon and Southern India in 1889 and 1890 Sir John Farmer gave at Oxford a most interesting lecture on his experiences. I recall two of his observations which have always seemed to me most illuminating. One concerned a *Loranthus*, which is so successful that it threatens the very existence of certain introduced trees. It possesses a viscid fruit which adheres to stem and leaves; then from the seed the embryo puts out a sucker borne at the end of a rather thick stalk which curls down and fixes itself to anything it touches. The stalk then straightens and the fruit, containing the germinating seed, is borne aloft. If, however, as he believed, the sucker becomes attached to an unsuitable surface, the stalk bends over again and makes another attempt to reach a living structure which can be penetrated, and if this fails the process continues, causing the fruit to travel in search of favorable opportunities, naturally denied to those which he often saw thickly covering the telegraph wires in the Nilgiri Hills.[14]

The second observation was made upon flowering plants which depend for cross-fertilization on insect-visitors and the honey which attracts them. Such flowers are well known to be robbed by insects which bite their way in and steal the honey without doing their work. Now Sir John Farmer observed that in certain species this difficulty was met by the development, on the outside of the flower, of special glands attractive to a bodyguard of ants so that the lazy visitors would be compelled to seek the proper entrance and the thieves driven away. This observation has always seemed to me especially significant, as showing how the simple operation of natural selection may simulate a rather elaborate process of reasoning. We may wonder whether it would have satisfied the zoologist of whom Darwin wrote to Lyell: "Dr. Gray of the British Museum remarked to me that *'selection* was obviously impossible with plants! No one could tell him how it could be possible!' And he may now add that the author did not attempt it to him!"

But if either or both of these interpretations should be disproved, if the ants in these and other analogous associations should be shown, as some believe, to be parasites doing no useful work for the plant—what then? Well, once again hypothesis will have played a fruitful part in stimulating and guiding research.

An often repeated objection to natural selection is the difficulty or impossibility of accounting for the earliest stages of useful structures. It is, of course, unwise to attempt an explanation of an unknown origin. We can only await further discoveries, and oftentimes admit that there is little hope of success. But the difficulty is frequently completely met by Anton Dohrn's principle of "change of function." A new function is often taken over by an organ adapted to perform another, the two at first overlapping and the younger gradually supplanting the older. The various uses of vertebrate limbs supply a good illustration.

Another valuable principle, working in association with Anton Dohrn's, is the "Organic Selection" of Mark Baldwin, Lloyd Morgan and Fairfield Osborn. The power of individual adaptability "acts as the

[12] An answer to the criticisms in this address appeared in the Introduction to *Essays on Evolution*, Oxford, p. xliv, 1908.

[13] *Proc. Roy. Soc.*, B., vol. 101, pp. i, ii, 1927.

[14] My friend has kindly refreshed my memory on some of the details.

nurse by whose help the species . . . can live through times in which the needed inherent variations are not forthcoming." But this power of adaptability is itself a product of selection. "The external forces which awake response in an organism generally belong to its inorganic (physical or chemical) environment, while the usefulness of the response has relation to its organic environment (enemies, prey, etc.). Thus one set of forces supply the stimuli which evoke a response to another and very different set of forces."[15]

What other theories of evolution have been offered to us by those who would reject or limit the power of natural selection? Some of them have been mentioned by a writer in a recent number of *Nature*[16]—"orthogenic variations," "established organic architecture," "metabolic routine," "laws of growth" and "conditions of organic stability." Others were named in Sir Peter Chalmers Mitchell's Huxley Memorial Lecture in 1927, and I agree with his description of them as a "brood of imaginary vital forces, gods placed in machines to account for modes of working we do not understand"; although, in many instances, some supposed manifestation of an internal developmental force receives a ready explanation along the lines suggested by H. W. Bates in his classical paper:[17]

> The operation of selecting agents, gradually and steadily bringing about the deceptive resemblance of a species to some other definite object, produces the impression of there being some innate principle in species which causes an advance of organization in a special direction. It seems as though the proper variation always arose in the species, and the mimicry were a predestined goal. [Then, after mentioning other suggested hypotheses, he concludes that all are] untenable, and the appearances which suggest them illusory. Those who earnestly desire a rational explanation, must, I think, arrive at the conclusion that these apparently miraculous, but always beautiful and wonderful, mimetic resemblances, *and therefore probably every other kind of adaptation in beings*,[18] are brought about by agencies similar to those we have here discussed.

The writer in *Nature* who marshalled his array of supposed developmental forces contrasted with them "the old nightmare view of evolution as a chapter of accidents." Well, a nightmare is not uncommon as a result of imperfect digestion!

The concluding section of the address will be almost entirely devoted to recent work with a direct bearing on Darwinian evolution—the researches upon mimicry and allied subjects undertaken by a band of brother naturalists widely scattered over the world. My greatest scientific interest and delight have been found in this work, and to it for nearly fifty years all available time has been given. The preparation lies far back in childhood, for my earliest memories are of living insects; and then at a fortunate period I read Professor Raphael Meldola's translation, with his valuable notes, of Weismann's "Studies in the Theory of Descent." He soon became my dear friend, and for nearly a quarter of a century I relied "probably even more than I am myself aware upon his sympathy and help."[19]

I would ask any naturalist who feels inclined to criticize the amount of space given to insect-mimicry in this address, to remember the words of H. W. Bates —"The process by which a mimetic analogy is brought about in nature is a problem which involves that of the origin of all species and all adaptations."[20]

The evidence for evolution by natural selection to be briefly described is in large part associated with the name of Fritz Müller, the illustrious German naturalist of whom Sir Francis Darwin wrote—"The correspondence with Müller, which continued to the close of my father's life, was a source of very great pleasure to him. My impression is that of all his unseen friends, Fritz Müller was the one for whom he had the strongest regard."[21] These words enable us to realize the special value and interest of Darwin's letters to Fritz Müller, the noble gift which the British Association has received within the last few months from Professor Fairfield Osborn.

Many of Fritz Müller's letters on insect mimicry and allied subjects were sent by Darwin to Professor Meldola, who communicated the observations to the Entomological Society of London,[22] of which he was an honorary secretary.

Whenever I have brought some striking example of insect mimicry to Sir Ray Lankester, my dear friend and the friend of many here, his comment was always the same—that it was a convincing proof of evolution by natural selection, and that he was unable to understand how any naturalist could come to a different conclusion. And yet, as we know, many have done so and probably many do so still. I hope, therefore, that it may be interesting and perhaps convincing to some unbelievers to refer to the two plates recently

[15] Poulton in *Proc. American Assoc. for Adv. Sci.*, vol. xlvi, p. 241, 1897.

[16] Vol. 127, p. 479, March 28, 1931.

[17] *Trans. Linn. Soc. Lond.*, vol. xxiii. (1862), Pt. III (1862), Mem. XXXII, p. 514.

[18] Italicized for the purpose of this address.

[19] "Essays on Evolution," p. ix. This work is dedicated to Raphael Meldola.

[20] *Ibid.*, p. 511.

[21] "Life and Letters of Charles Darwin," London, vol. iii, p. 37, 1887.

[22] Darwin's letters to Meldola, including ten referring to Fritz Müller, are printed in "Charles Darwin and the Theory of Natural Selection," Poulton, London, 1896. The originals, with many of F. Müller's letters, were presented by Professor Meldola to the Hope Library, Oxford Univ. Museum.

published in the Transactions of the Entomological Society.[23]

The moth model and butterfly mimic, beautifully illustrated on plate XIV, really speak for themselves; but it must be explained that the resemblance between the patterns is much closer on the upper surface of the wings than on the under; that the orange patch evidently becomes a conspicuous warning mark (aposeme) in which the position of rest when the insects hang with drooping wings and the under side of the body is uppermost; that the position of the mimic's patch on the parts of the wings which cover the body and not on the body itself, as in the model, is evidence of selective elimination guided by the sense of sight; also that model and mimic fly together round the tops of trees, the former being much the commoner. I owe this most interesting example to my kind friend, Dr. Karl Jordan, of the Tring Zoological Museum.

The second example, shown on plate XV, is of a very different kind, but I think equally interesting and convincing. The oval yellow masses of silk spun on the outside of their cocoons by the caterpillars of the W. African Bombycid moth, *Norasuma kolga,* closely resemble the cocoons constructed by Braconid parasites which have devoured a larva or pupa. The appearance is, I believe, well known to nearly everyone and is especially common in the autumn, when the dead or dying caterpillars of the Large Garden White butterfly may be seen on walls and fences, bearing the yellow cocoons of the parasitic larvae which have destroyed them. It has sometimes been thought that the object of the pretended Braconid cocoons is to deceive the female Bracon in her search for caterpillars in which to deposit her eggs, but this is most improbable because these parasites are guided by other delicate senses in addition to sight, which perhaps is not employed for this purpose; above all, because the eggs which are the ultimate cause of parasitic cocoons like the pretended ones, would have been laid far back in the life of the victim. It is probable that the conspicuous yellow color is advantageous to the parasites, for the small cocoons are very tough and contain but a small amount of food. A few experiments, perhaps a single one, would teach a bird that a cocoon bearing these yellow masses contains only a shrunken skin, and also that the yellow cases themselves are not worth opening. The yellow warning color is advantageous to the parasites "because enemies are all the more readily discouraged from making attempts which would incidentally lead to the destruction of some of them. Hence the obvious advantages conferred by false cocoons of parasites when mistaken for real ones."[24] This interesting adaptation was discovered by my old friend, Dr. W. A. Lamborn, O.B.E., who, a little earlier, had found another example in which the same deceptive resemblance was brought about in a totally different way. The cocoon of another West African moth (*Deilemera antinorii*) he observed to be covered with little yellowish spheres so very like Braconid cocoons that he kept them and watched for the parasites to emerge. It was finally discovered that the "cocoons" are spheres of hardened froth evacuated by the *Deilemera* caterpillar and then attached with silk to the outside of its cocoon. The late Mr. G. F. Leigh, of Durban, was similarly deceived by an allied East African species and threw away three or four cocoons, thinking they had been parasitized.

What interpretation can be suggested for adaptations such as these, except the selection and accumulation of small variations? And it is to be remembered that even in the mimetic butterfly of Plate XIV the associated instinct—the attitude assumed at rest—is an essential element in the resemblance, while in the construction of the false cocoons shown on Plate XV, the instinctive actions are nearly everything. It is also to be remembered that these actions are prophetic, destined for the protection of a future pupal stage. This fact is so interesting and significant in its bearing on theories of evolution that I venture to bring before you two other especially striking examples, although, of course, prophetic activities are displayed by every caterpillar in spinning its cocoon or otherwise preparing for pupation.

The larva of an African Tabanid fly (*T. biguttatus*) lives and becomes a pupa in mud which, in the dry season, is traversed by cracks so wide that they would often expose the insect in its most helpless stage. But Dr. Lamborn discovered that the maggot has prepared for this danger. It carves out a cylinder from the surrounding mud, making a line of weakness by means of a close spiral tunnel; then it enters just below the top of the cylinder and pupates in its center. The pupa when mature bores its way through the hard mud covering and the fly emerges. Dr. Lamborn was led to his discovery by observing the tops of the cylinders, of about the size of a penny, often with the pupal shell protruding from the center; also by noticing that the cracks running in all directions stopped short when they reached the cylinders. I feel sure that you will agree with the words written by Professor J. M. Baldwin when he read the account

[23] *Trans. Ent. Soc. Lond.*, vol. lxxix (pls. xiv and xv, 1931). The cost of reproduction has been borne by the Fund for Promoting the Study of Organic and Social Evolution, presented to Oxford University by my dear friend Professor James Mark Baldwin.

[24] *Trans. Ent. Soc. Lond.*, vol. lxxix., p. 397, 1931. This paper gives full references to all the observations here referred to in the description of pls. xiv and xv, as well as others necessarily omitted.

of this instinctive behavior—"As to the discovery of Lamborn, it seems *complete*—one of those rare cases of a single experience being sufficient to establish both a fact and a reason for the fact! It is beautiful."[25]

The other observation is also of especial interest, being an arresting example of the attainment of the same end by a different and unusual means. In leaving their cocoons some insects gnaw their way out, others make use of holes drilled by pupal spines, as in the last-mentioned Tabanid fly. The well-known "Puss-moth" (*Dicranura vinula*) has been shown by O. H. Latter to soften the hard cocoon with a secretion of caustic potash. Many caterpillars in spinning their cocoons make special provision for easy emergence and difficult entrance, on the reversed principle of the lobster-pot, a beautiful example being our own "Emperor Moth" (*Saturnia pavonia*). Now these preparations are made in spinning the cocoon, but the caterpillar of an Indian moth allied to our "Lappet Moth" first nearly finishes its cocoon and then deliberately bites two slits in it. As Lt.-Col. F. P. Connor[26] has written: "It was a striking fact to observe how the larva, after all but completing the cocoons, always "remembered" to destroy part of its laboriously built home by biting out two deep clefts at one end, and how the valve-like door thus made was patiently tested several times to make certain of its being of the right size, and then carefully closed on the inside with a little soft silk which would not interfere with the emergence of the imago." In testing the opening the caterpillar extended "half its body out of the cocoon to assure itself that the vent was large enough." How is it possible to apply any Lamarckian theory of inherited experience or of effort and improvement following from experience, to examples like these? The experience of ease or difficulty in emergence in the last example, of failure or success in evading enemies in the others, will come, not in the stage which made the preparation but in a later one, and should it come, the chances of handing on its lessons would be negligible. "The prime necessity for an insect, as for all animals which can not in any real sense contend with their foes, is to avoid experience of them altogether."[27] And the cocoon-making activities described above are preparations, made long beforehand, for the avoidance of experience.

I propose now to refer briefly to some of the objections which have been raised against the opinion that protective and mimetic resemblances have arisen by natural selection, and to consider alternative suggestions. Dr. Paul Vignon, in his fine and beautifully illustrated monograph[28] on the leaf-like Long-horned Grasshoppers (*Tettigoniidae*) of tropical America, comes to the conclusion that the detailed resemblance to decayed leaves or leaves apparently mined or eaten by caterpillars, is useless, his reason being that other species with the much simpler likeness to uninjured leaves are able to hold their own in the struggle with greater success, as shown by their comparative abundance. Therefore he considers the details as a "decoration" unnecessary in the life of the insect, agreeing with Brunner's theory of "Hypertely."[29] I believe, on the contrary, that the detailed resemblance to one out of many different appearances which the same object may present—*e.g.*, to a leaf gnawed into a particular shape by a caterpillar—would often mean safety to a rare, hard-pressed species but great danger to a common one; for the sharp senses of enemies would quickly detect the meaning of that one shape, and then a special search would be made for it.[30] I am sure, however, that every one will share the author's hopes for further observations on the living insects in their natural surroundings.

On the subject of the protective resemblance to leaves I can not resist the temptation to say a few

[25] *Proc. Ent. Soc. Lond.*, vol. v., p. 14, 1930. Lamborn's discovery is published in *Proc. Roy. Soc.*, B., vol. 106, p. 83, pl. v, 1930. As this address was being written a letter arrived from my friend at Fort Johnston, Nyasaland, telling me that he has just bred another Tabanid fly, at present undetermined, from a mud cylinder like that of *T. biguttatus*.

[26] *Journ. Bombay Nat. Hist. Soc.*, vol. xxvi., p. 691, 1919.

[27] The arguments in this paragraph were brought forward in the unpublished discussion "Are Acquired Characters Hereditary?" at the Manchester Meeting, September 5, 1887 (*Report*, p. 755). The later occasions on which they were developed and recorded are mentioned on p. 155, n. 1, of *Essays on Evolution*, where they are reprinted (pp. 117, 118, 154–160).

[28] *Arch. du Mus.*, 6, V, p. 57, 1931. See also his *Introduction à la Biologie Experimentale. Les êtres organisés. Activités, instincts, structures.* Encyclopédie Biologique, VIII, Paris, 1930.

[29] Professor J. M. Baldwin has kindly written the following note on a subject (recalled by Dr. Vignon's memoir) we had discussed together: "The continued lack of enthusiasm for natural selection in France seems at first glance remarkable. It seems inconsistent with the French love of logical "clearness and distinctness" given as the criteria of truth by the French philosopher Descartes, for whom his countrymen have the greatest veneration. But the tendencies shown in the work of Delage and Giard in the last generation appear still in the publications of such thinkers as Le Roy and Brunschweig. Naturally I take no account of special researches of younger biologists with which I am not familiar. The philosophical writers, at least, retain a diluted Lamarckism, somewhat hesitant, it is true, and always on the defensive. It is part of the vitalism expressed by Bergson in the terms 'élan vital' and 'évolution créatrice.' The positivism of Auguste Comte is still completely demoded, except in the sociological work of Durkheim and Lévy Bruhl, in which the question of the method of biological evolution has no place. The revolt against Bergsonian vitalism in the intellectual world has been directed against its mysticism, but has not extended itself to questions of biology."

[30] *Proc. Ent. Soc. Lond.*, p. cxlv, 1924.

words about W. J. Kaye's discovery of the part played by the dead-leaf-like under surface of the tropical American butterfly *Protogonius*.[31] The upper side of this butterfly roughly resembles the conspicuous warning pattern of the predominant mimetic association of its locality, changing when the pattern changes as we pass from one area to another—always a mimic although always a poor one. At rest, with folded wings, the resemblance to a dead leaf is perfect. Now Kaye observed that when the open wings of these butterflies were seen from below against the sky the appearance was that of the upper surface, so that at first he thought they must be flying upside down. When, however, he examined them he found that the apparently opaque dead-leaf-like under side was completely overwhelmed by the stronger contrasts of the upper surface. The wings of *Protogonius* were shown in this section at Liverpool in 1923, when a friend who does not greatly favor an interpretation based on natural selection, pointed out rather triumphantly that the dark and the light parts of the two patterns correspond respectively. But this is precisely the kind of result which affords proof of evolution by selection. The two patterns certainly have a common plan, but by stippling here, softening there, and the addition of delicate tints in streaks and washes, the conspicuous, strongly contrasted mimetic pattern of the upper surface is replaced on the under by a beautiful and detailed likeness to a dead leaf.

Before considering the objections to the theory of mimicry it is necessary to devote a little time to Fritz Müller's interpretation of the resemblances which Bates was unable to explain. His difficulty was caused by the remarkably detailed likeness between many species in the two groups which he called *Danaoid* and *Acraeoid Heliconidae*, groups really widely separated and now known respectively as the *Ithomiinae* and the *Heliconinae*, both conspicuous and distasteful, and providing models for other butterflies and moths, yet often mimicking each other, the *Heliconinae* being commonly mimetic, the *Ithomiinae* rarely. Bates was referring to these resemblances in the following sentence: "Not only, however, are *Heliconidae* [*viz.*, both the *Danaoid* and *Acraeoid* groups] the objects selected for imitation; some of them are themselves the imitators; in other words, they counterfeit each other, and this to a considerable extent."[32] The theory of mimicry which bears Fritz Müller's name was suggested by him in 1879.[33] Briefly, the theory rests on the advantage of a combined advertisement in saving lives that would have been lost in the experimental attacks of enemies. Batesian mimicry, on the other hand, rests on the advantage of a false advertisement, leading a palatable insect to escape because mistaken for a distasteful one. Much controversy has arisen over the mathematical aspect of the problem, but this can not be considered on the present occasion. I have been led to believe that Müllerian mimicry is more important than Batesian because models and mimics are so commonly found in the same presumably distasteful group, and because the resemblances which were not explained by Bates' theory are so much commoner than he supposed. Thus the distasteful Heliconine butterflies, among which he recognized mimics of the Ithomiines, are also themselves divided into groups, of which one mimics the other so perfectly that the real difference was for many years unsuspected.[34] And this is equally true but far more striking in the Heliconine mimics of Ithomiines because the patterns are very elaborate, so much so indeed that these mimics are among the most remarkable in the world.

One or two more examples which suggest the prevalence of Müllerian mimicry may be mentioned. The intricacies of systematics being unnecessary for the appreciation of the argument, I propose to reduce them to a minimum. The "White Admirals" of the northern belt have been separated into different genera, but they are all nearly related with very similar life-histories. They are, except when modified by mimicry, dark butterflies with conspicuous white markings displayed in a sailing flight. In Europe they are mimicked by the female of our "Purple Emperor" and other butterflies, including a black-and-white invader (*Neptis*) from the south, this latter butterfly belonging to a group which itself provides models for mimicry. Any doubt about the mimetic resemblance of the female Emperor is dispelled when we remember that numerous allies of these Admirals in tropical America (*Adelpha*) are there mimicked by females of butterflies allied to the Emperors (*Chlorippe*). In North America some of the White Admirals possess the black-and-white pattern, one (*astyanax*) is a mimic of a distasteful Swallowtail (*P. philenor*), but at the same time is considered by Scudder to be the model for a female Fritillary. Others are beautiful imitations of Danaine invaders from the Old World, and the mimicry is so recent that one of these (*archippus*) and also *astyanax* can breed with their black-and-white ancestor (*arthemis*)

[31] *Ibid.*, p. xcviii, 1922; p. xxxvii, 1923. See also p. xl for Lord Rayleigh's notes on the optical interpretation.

[32] *Ibid.*, p. 507.

[33] *Kosmos.* The paper was at once translated by Meldola and published in the *Proc. Ent. Soc. Lond.*, p. xx, 1879. A preliminary paper containing everything essential to his theory of mimicry was published by Fritz Müller in *Zool. Anzeiger* (Carus), I, pp. 54, 55, 1878. Translation by E. A. Elliott in *Proc. Ent. Soc. Lond.*, p. xxii, 1915.

[34] W. J. Kaye in *Proc. Ent. Soc. Lond.*, p. xiv, 1907; H. Eltringham in *Ibid., Trans.*, p. 101, pls. XI–XVII, 1916.

and produce intermediate offspring.[35] There is finally a species (*lorquini*) on the Pacific Coast which is a mimic of a southern invader (*californica*) closely related to the tropical American Adelphas. This last, too, is of especial interest because the mimicry is only developed where the two butterflies overlap, and dies away to the north and east where *lorquini* spreads beyond the range of its model.[36]

We have seen that the Adelphas of the New World are models, but the corresponding African representatives of the White Admirals, the Pseudacraeas, are, with one or two exceptions, mimics, resembling certain Acraeine butterflies conspicuous in their localities, and in two instances Danaines, one of the models being *D. chrysippus*.

These tangled relationships of models and mimics in the great group of "White Admirals" and their allies are in my opinion impossible to reconcile with the Batesian theory, but in every way consistent with the Müllerian. It will be necessary to return to the African Pseudacraeas, a little later, but I will first mention one more example which, I believe, supports the same conclusion.

During the meeting of the Association at Toronto in 1897, I met Dr. Gustav Gilson, of Brussels, who was about to visit Fiji and very kindly promised to collect butterflies for me. Among the specimens received were two species of *Euploea*, one of which had obviously been modified in mimicry of the other. Now the Euploeas are among the most distasteful and most commonly mimicked butterflies in the world, and I became extremely anxious to obtain more specimens from different islands of the Fijian and other groups. Finally, after waiting more than twenty years I received a very kind letter from Mr. Hubert W. Simmonds, who had heard of my wants, which he then proceeded to supply most generously and efficiently, enabling me to study this and other equally interesting problems. There is not now the possibility of describing the results,[37] but I will mention, as bearing on the Müllerian theory, that the mimicking *Euploea* of Fiji is found to be a model on Wallis Island, and the model of Fiji its mimic; while on Fortuna Island, 150 miles away, the Wallis model is absent, while the other *Euploea* is present, but unmodified by mimicry.

[35] *Proc. Ent. Soc. Lond.*, p. xciv, 1916. Abstract of W. L. W. Field's three valuable papers in *Psyche*.

[36] *Trans. Ent. Soc. Lond.*, p. 447, 1908. *Lorquini* and its model are represented on pl. XXV, which also shows a reciprocal approach of the latter towards its mimic. Owing to the kindness of Commander C. M. Dammers I have been provided with Mimicry in the N. American "White Admirals," here very briefly summarized, is the opportunity of renewing this investigation with far more extensive material, considered in detail in the above paper and in *Proc. Acad. Nat. Sci. Philadelphia*, p. 161, January, 1914.

[37] A full description appears in *Trans. Ent. Soc. Lond.*, p. 564, pls. XXIX–LIII, 1923.

The year before Fritz Müller proposed his theory of mimicry in 1878, he published a paper which was probably the preparation for it—the paper in which he explained the meaning of the gregarious habit in certain distasteful insects. Thus, writing of the dull brown caterpillars of two American butterflies, he suggested that the social habits "which lead them to congregate in large numbers make up for their want of color, since their offensive odor then gives timely warning to an approaching enemy."[38] This interpretation has recently been adopted for the interesting and hitherto puzzling habits of *Heliconius charithonia*, which collects into crowded groups on bare twigs in the evening, as was first recorded by Philip Gosse in Jamaica in 1851 and since then by numerous observers. *H. charithonia*, which belongs to the distasteful Heliconines referred to on page 354, and is itself mimicked by other butterflies,[39] has been carefully studied by Dr. F. M. Jones, and its gregarious habits described in detail in his paper "The Sleeping Heliconias of Florida."[40] He here suggests that the warning characters may be rendered more effective at night "by the close proximity of large numbers, under these conditions readily recognizable by form, color, or *scent*, as identical in kind and inedible; for thus the injury or destruction of one of the group might conceivably work for the protection of the many." It may be added that the choice of leafless twigs for a resting-place obviously enhances the conspicuousness of the assemblage.

We must now return to one of the African Pseudacraeas, a wide-ranging species (the Linnean *eurytus*) which subdivides into a number of local forms mimicking the local Acraeine models. This species is represented in Uganda by a race (*hobleyi*) so significant in its bearing on evolution by selection that it is necessary to give a little time to it. *Eurytus hobleyi* appears in three forms—two, with male and female alike, mimicking two Acraeine butterflies (*Planema*) differing in color but also with male and female alike. The third, with male and female very different, mimics a third *Planema*, the sexes resembling the corresponding sexes of the model. Now these four mimetic forms —for the male and female of the last were believed to be of different species—have all been described and named as distinct, and there was great astonishment and even some incredulity when Dr. Karl Jordan, relying on structural features, pronounced them to be one. After many efforts to test this conclusion by

[38] *Kosmos*, December, 1877. Translation by Professor R. Meldola in *Proc. Ent. Soc. Lond.*, pp. vi, vii, 1878.

[39] W. J. Kaye in *Proc. Ent. Soc. Lond.*, vol. v, p. 89, 1930.

[40] "Natural History," *Journ. American Mus. Nat. Hist.*, vol. xxx., p. 635. A full abstract, with references to other observations, in *Proc. Ent. Soc. Lond.*, vol. vi., p. 4, 1931.

breeding, a cable was received from Dr. Hale Carpenter on Bugalla Island (N.W. Victoria Nyanza), giving the information which proved that Dr. Jordan was right.

Many other families were then bred by Dr. Carpenter, and these, with his captured specimens, showed that, in the islands, the three forms run into each other, being connected by an abundance of transitional varieties which are extremely rare on the adjacent mainland of Uganda. The significance of this is obvious when it is realized that the models are for some unknown reason comparatively scarce on the islands.[41]

The same conclusion is enforced by the wonderful families of *Papilio dardanus,* bred by Dr. V. G. L. van Someren and Canon K. St. Aubyn Rogers from localities near Nairobi. Now in the families of this butterfly that have been bred in other parts of Africa—by Carpenter in Uganda, by Lamborn on the W. and E. coasts, by Swynnerton in S. E. Rhodesia, and by Leigh in Natal, the mimetic forms of the females are sharply separated—a fact which led to the mistaken conclusion that these patterns appeared fully formed and complete, each as a single variation. But in the Nairobi families, as in the Pseudacraeas of the Uganda islands, all kinds of transitional forms appear and, most striking of all, the *trophonius* female mimicking the Danaine *D. chrysippus* has not been bred but only its primitive ancestor *lamborni,* and this has appeared often, although very rare in other localities. Here, too, the same explanation holds, for Dr. van Someren and Canon Rogers have observed that for some cause, perhaps the elevation, the Danaine models are much scarcer than their mimics, and can not be supposed to influence the selective elimination as in other parts.

These two striking examples offer, I believe, convincing evidence of the power of selection in the evolution and preservation of mimetic patterns; also that the evolution was by small variational steps. The remarkable families of *Hypolimnas bolina,* bred by Mr. H. W. Simmonds in Fiji, supply further evidence in favor of this last conclusion.[42]

Admitting, as claimed and, I believe, proved above, that selection is essential for the evolution of mimicry, nevertheless the abundance of mimetic forms when their models are rare, and still more when they are absent altogether, does make it difficult to feel confident that natural selection, in its accepted sense of survival of the fittest, has always been the cause. This doubt was first raised in my mind by the consideration of the Oriental butterfly, *Papilio polytes,* and led to the belief that in this and probably other predominant species the absence of the model finally leads to the disappearance of the mimetic pattern, "although the species that bore it remains as abundant as before. The survival or extinction of the species is not affected: all that has happened is the survival or extinction of a pattern borne by a certain proportion of the individuals of the species. When these disappear, other individuals with another pattern take their place."[43] For this process Professor Julian Huxley has suggested the term "intraspecific selection," to be contrasted with natural selection which ensures the survival of the species in its organic environment and, therefore, in a struggle which is *inter*-specific. Mr. A. J. Nicholson[44] has independently proposed a similar hypothesis but seeks to carry it much further, so as to cover all examples of mimicry and protective resemblance. My reasons for disagreeing with this opinion are given in the above-mentioned paper on intraspecific selection.

Certain criticisms which have been brought against the theory of mimicry have followed from the erroneous assumption that the warning colors of the models imply complete immunity from attack, even by parasites, an assumption unfortunately made by Haase in his important and valuable work.[45] Of course no species enjoys absolute immunity, and if it did so the enjoyment would be brief, for it would rapidly destroy its own means of existence. Furthermore we know, as my friend Dr. Hale Carpenter showed to this section at Birmingham in 1913, that the species distasteful to insectivorous animals (although not by any means entirely free from this danger) are specially subject to parasitic attack. At the same city, in 1886, I brought before this section the theory of a compensating principle[46] which would check the increase of distasteful insects; for when other food became scarce they too would be devoured, and then their conspicuous appearance and slow movements would lead to their easy capture. This theory was supported by experiments which proved that insectivorous animals, when they are sufficiently hungry, will in fact eat the distasteful species, although often with signs of disgust. The experimental method, necessarily employed in testing the above-mentioned hypothesis, and also of much value when other evidence is wanting, was criticized by W. L. McAtee in a paper published in 1912.[47] I

[41] *Trans. Ent. Soc. Lond.*, p. 706, 1912; p. 606, 1913; p. 84, 1920; p. 469, 1923.

[42] *Trans. Ent. Soc. Lond.*, pls. XLV–LIII, 1923.

[43] Poulton in *Proc. Zool. Soc. Lond.*, p. 1037, 1928. The term "Intraspecific Selection" was introduced in this paper, which also quotes the essential passages from the paper (*Bedrock*, vol. ii., No. 3, p. 295, October, 1913, in which the hypothesis was first suggested.

[44] "A New Theory of Mimicry in Insects," *Australian Zoologist*, vol. v., pt. 1, p. 10, pls. I–XIV, November, 1927.

[45] *Untersuchungen über die Mimicry*, Stuttgart, 1891–3.

[46] Considered in detail in a paper published in the following year: *Proc. Zool. Soc. Lond.*, p. 191, 1887.

[47] "The Experimental Method of Testing the Efficiency of Warning and Cryptic Coloration in Protecting Ani-

was probably mistaken in not at once writing a detailed reply to these criticisms, which were not only directed against the conclusions drawn from experimental feeding, but also against other conclusions on which the theory of mimicry is founded. On the other hand, there was much to be said for waiting until far more evidence had been collected, and now, after nearly twenty years, it may be fairly maintained that such evidence has been forthcoming.

In the first place it may be granted that, apart from its special value as a test, the experimental method is, in this investigation, very inferior to the direct observation of attacks made upon insects by birds and other enemies in their natural surroundings and undisturbed. It is impossible on this occasion to attempt to give any account of the great number of such records which have accumulated since the appearance of McAtee's criticisms. I will, however, mention two sets of observations. In 1927 Dr. Hale Carpenter kindly sent me the wings of Uganda hawkmoths—twenty-one specimens and seven species—found on the floor of a rest-house where they had been dropped by bats hanging in the roof. This interesting observation suggested an examination of moths' wings dropped by British bats—an ideal means for discovering their true preferences. Wings representing 1,328 moths were collected in sheltered places frequented by bats—probably always by the long-eared bat (*Plecotus auritus*). All the specimens except sixteen belonged to species with protective (procryptic) colors and habits. The exceptions included relatively conspicuous species shown by experiments on other animals to be rather distasteful (sometimes accepted, sometimes refused), also species of which the palatability is unknown. Not a single specimen with a striking warning pattern was present.[48]

The second series of observations is now being undertaken at Vineyard Haven, Massachusetts, by Dr. Frank Morton Jones, who has kindly written to me, explaining the details of the excellent methods he is employing. Insects, chiefly Lepidoptera and Coleoptera, of known species, are exposed on a feeding-tray in a favorable locality and the visits of birds watched at a distance through field-glasses. Thus on June 27 last, of 63 beetles belonging to nine species placed on the tray, there remained in 30 minutes, after 22 bird-visits (three species), 15 beetles of one red-and-black species. Thus 48 beetles of eight species were taken and all the 15 of the ninth species were untouched. Dr. F. M. Jones is also attempting to form a scale of distastefulness by observing the reactions of a common species of ant to the insects employed in the experiments.

One of the chief criticisms made by McAtee, and made in this country also, was the insufficiency of the evidence that butterflies are commonly attacked by birds, the enemies believed to be the selective agents in the evolution of mimicry. McAtee, in support of this objection, quoted the results of an American agricultural investigation in which an enormous number of birds' stomachs had been examined and remains of butterflies found in only an insignificant proportion. This criticism had been in great part met beforehand in a paper[49] published by Sir Guy Marshall in 1909; and more recently C. F. M. Swynnerton[50] and W. A. Lamborn[51] have conclusively shown that butterflies are rapidly reduced to such minute fragments in a bird's digestive tract that examination with the compound microscope is necessary in order to obtain trustworthy results. Furthermore, it is only in recent years that the imprint of a bird's beak on a butterfly's wing has been noticed; but now that attention has been directed to this evidence it is found to be quite common—a good example of the fertile but, for the uncritical, the dangerous principle that an observer only finds what he looks for.

It is possible that the mistaken assumption of the immunity of models has played a part in prompting Dr. Bequaert's interesting paper on the enemies of ants.[52] Admitting the existence of these enemies and the certainty that the list will be immensely lengthened, it still remains that ants are "the most powerful of insects, ever-present and aggressive in all habitable parts of the earth."[53] And it is difficult to reconcile with Dr. Bequaert's opinion that they are valueless as models, the fact that my friend Mr. H. St. J. K. Donisthorpe has, since 1891, discovered, in the nests of British ants, "204 species of insects, spiders and mites new to the country, including 74 new to science. Of these guests 28 are mimics of ants. . . . He has also recorded 34 mimics living independently of ants."[54] I believe that most naturalists will conclude

mals from their Enemies.'' *Proc. Acad. Nat. Sci. Philadelphia*, pp. 281–364, 1912.

[48] *Proc. Zool. Soc. Lond.*, Pt. 2, p. 277, 1929. The interesting plates I–III in *Proc. Ent. Soc. Lond.*, vol. vi., 1931, provide evidence of the same value as that furnished by the rejected wings. They show young cuckoos being fed by fosterers with ''Small Garden White'' butterflies, in Sussex, photographed by Mr. H. F. Chittenden, and Cumberland, by Mr. A. G. Britten. Dr. J. G. Myers' observations on the insect food of the Coati (*Nasua*) were also in large part made under natural conditions (*Ibid.*, vol. v., p. 69, 1930). See also Capt. C. R. S. Pitman's experiments on an African Lemur (*Periodicticus*) on p. 91, and in vol. iv., p. 90, 1929.

[49] *Trans. Ent. Soc. Lond.*, p. 329, 1909. See especially pp. 336, 337.

[50] *Linn. Soc. Journ. Zool.*, xxiii, p. 203, 1919. Abstract in *Proc. Ent. Soc. Lond.*, p. xxxii., 1915.

[51] *Proc. Ent. Soc. Lond.*, p. xxvi., 1920.

[52] *Bull. Am. Mus. Nat. Hist.*, vol. xlv., p. 271, New York, 1922.

[53] *Zoolog. Anz.* (Wasmann-Festband), p. 86, 1929.

[54] *Ibid.*, p. 84. Quoted from ''Guests of British Ants,'' Donisthorpe, London, 1927. The numbers have been brought up to date with the kind help of the author.

from these discoveries in Great Britain and Ireland, and from the remarkable profusion of ant-mimics and ant-associates in the tropics, that in spite of all attacks, these insects possess in the highest degree the qualities which render them valuable as models.

I now propose to direct your attention to certain experiments and observations which throw light on the brain and senses of vertebrate enemies of insects. Although the experiments brought before this section at Manchester in 1887 were few and single, I believe, and I still believe, they were crucial, and proved beyond doubt that the mind and memory of even a reptilian enemy—and of course far more probably an avian enemy—are such as we should expect to find in the selective agents which have brought about the evolution of mimicry in insects. I refer to the chameleon, which, after rejecting a bee which it had captured the moment after its introduction into the cage—after this single experience—would never touch another, although offered from time to time during many months; also to the lizard, which approached a hornet-like clearwing moth with the utmost circumspection, and in finally seizing it kept as far as possible away from the supposed sting, and then, evidently realizing from the texture that the insect was not a wasp or hornet, proceeded to eat it without further caution, and a few days later recognized another at sight and instantly devoured it.

It is not to be hoped that these experiments will carry the same conviction to those who only hear of the results and did not see them; but in recent years other evidence throwing much light on the faculties and behavior of birds has been steadily accumulating.[55]

The conclusions of the distinguished ornithologists, E. C. Stuart Baker and Rev. F. C. R. Jourdain, that the resemblance of cuckoos' eggs to those of the fosterers has been evolved through the selective destruction of the less like by the birds which would otherwise have been victimized, obviously bear closely on the development of a mimetic pattern in insects. The similarity between the two selective processes, both leading to a superficial likeness which changes with the geographical changes of the models, was made the subject of the address to the Entomological Society in January, 1926, and led to the last words addressed to me, although indirectly, by William Bateson, the distinguished ex-president of this section and of the association, whose loss we all deplore. Not many days before his death he was present at the meeting and told a mutual friend that he was much interested in the observations and that they were quite new to him.

Evidence of a different kind, but probably very significant, is provided by the well-known African Honey Guide (*Indicator*) which directs man to a bee's nest and is repaid by a meal on the scattered larvæ. My friend, Dr. Neave, has told me that this bird, when insufficient attention is paid to its directions, becomes so noisy that game is disturbed, and he found it necessary, on hunting expeditions, to detail a couple of natives to follow the Guide and keep it quiet. How far the behavior of the bird is instinctive and how far intelligent is, I believe, unknown, but it is impossible to imagine a more fascinating subject for investigation.

Of more importance, because common to many species and known to exist in all the great tropical areas, is the nesting association between birds and the most formidable of insects—wasps and hornets; also with ants and termites. In the association with wasps naturalists have definitely stated that the birds begin to build close to the already constructed pendent comb of a wasp, while their nests are actually excavated in the termite-mounds and in the huge nests of tree-ants. This most interesting and significant behavior has been summarized for tropical America by J. G. Myers, who has confirmed the older records by his own observations and has also been led to the startling conclusion that at least one wasp tends regularly to make its nest besides the colonies of a tree-ant (*Azteca*). Notes on these associations in Africa have been written by A. Loveridge and V. G. L. van Someren; in India by E. C. Stuart Baker; in Australia by W. B. Alexander.[56]

The behavior briefly described in the last two paragraphs proves, I believe, that birds possess a brain and sense-organs such as would lead them, in seeking their food, to associate the qualities, favorable or unfavorable, with the appearance, and to remember and apply their experience, in fact precisely the powers required by a selective agent in building up a mimetic pattern.

To the above evidence may be added two examples of bird behavior in our own country. The cocoon of the common "Lackey Moth" is thick on the exposed surface but thin where it is spun on to a leaf. Birds have discovered this and peck a hole through the leaf and thin wall in order to abstract the chrysalis.[57] Many naturalists have observed that birds, although they frequently peck their way into the center of "bullet-galls" (often but erroneously called "oak-apples"), never do so when the enclosed insect has emerged, being doubtless guided by the sight of the small round hole or by tapping with the bill.[58]

What other hypotheses have been suggested by those

[55] Nearly all these observations are recorded or quoted with full references in the Proceedings of the Entomological Society of London in recent years, and will be easily traced.

[56] *Proc. Ent. Soc. Lond.*, vol. iv., p. 80, (America) 1929; p. 88 (Africa); p. 89 (India); vol. v., p. 111 (Australia) 1930; vol. vi., p. 34 (India) 1931.

[57] Observed by A. H. Hamm. *Ibid.*, p. xv., 1902.

[58] *Ibid.*, vol. iii., p. 50, 1928; vol. iv., p. 10, 1929.

who reject evolution by natural selection as the explanation of mimicry and allied adaptations? Some naturalists believe that the resemblances in question are accidental and of no biological significance. This opinion, although defended by such an eminent entomologist as Professor Handlirsch,[59] is not likely to be held by any one who has seriously considered examples such as those brought before you to-day, or has studied the geographical distribution of mimetic associations. Chance resemblances are, of course, bound to occur among the immense number of butterfly patterns throughout the world, but these will be as frequently found between the species of different countries as between those of the same country. Such truly chance likenesses in patterns have been examined by my friend, Dr. F. A. Dixey,[60] and have been shown to be relatively few and only to exist at all when the patterns are relatively simple. The distinguished mathematician, the late Professor Study, of Bonn, who was deeply interested in mimicry, has shown, in two of his last papers, the impossibility of an explanation based upon chance resemblance, and I believe that the same conclusion will be reached by any one who reads the chapter on mimicry in Dr. R. A. Fisher's recent work.

The view has sometimes been held that mimetic resemblances are due to model and mimic independently passing through the same stage of evolution, either as a whole or in the mimetic features only; or, as Darwin once suggested, "that the process probably commenced long ago between forms not widely dissimilar in color.[61] I remember, at the Leeds meeting in 1890, when Professor Patrick Geddes suggested the former interpretation, that the late Lord Rayleigh remarked, "How would you apply your explanation to the resemblance of insects to bark, or twigs, or leaves?"[62] It is strange that this fatal objection did not occur to Darwin, for Bates himself in the great paper had written: "I believe . . . that the specific mimetic analogies exhibited in connection with the *Heliconidæ* are adaptations—phenomena of precisely the same nature as those in which insects and other beings are assimilated in superficial appearance to the vegetable or inorganic substance on which, or amongst which, they live. The likeness of a beetle or a lizard to the bark of the tree on which it crawls can not be explained as an identical result produced by a common cause acting on the tree and the animal."[63]

Before concluding, a few lines must be devoted to recent work on sexual selection, first briefly introduced as a factor in evolution by Darwin in the Joint Essay. Nothing would have interested and pleased him more than discoveries which, following the splendid pioneer work of Fritz Müller, have been made in the epigamic structures and behavior of insects—the extensive observations on the scents of male butterflies, by Dixey and Longstaff, and on their scent-scales by Dixey; the structure and use in courtship of the scent-brushes of male Danaine butterflies, by Eltringham, Lamborn and Hale Carpenter; the extraordinary brushes protruded from the back of the head by the males of *Hydroptila* (Trichoptera), by M. E. Mosely and Eltringham; the courtship of Empid flies, including the spinning of a cocoon as a wedding gift by the male *Hilara,* by Hamm and Eltringham;[64] the fertilization of orchids (*Ophrys*) by male bees (*Andrena*) which, emerging before the other sex, are attracted by female-like appearances, and probably scent, of the flowers, by Pouyanne, confirmed by M. J. Godfrey and by Mrs. Coleman, who has observed the fertilization of an Australian orchid (*Cryptostylis*) by a male Ichneumonid (*Lissopimpla*), similarly attracted to the flower.

On two occasions I have been present when the late Lord Balfour expressed his opinion on the theories of evolution we have been considering to-day, and I am sure that naturalists will be glad to hear the conclusions reached by his keen and penetrating intellect on subjects in which, although without the time, or indeed the inclination to probe far into details, he took the keenest interest. We know that, even before he went to Cambridge in 1866, he had read and admired the "Origin," and we have been told by his nephew, Lord Rayleigh, of his "extraordinary faculty for getting hold of the essentials of a subject without apparently feeling the need for systematic study.[65]

Over forty years ago, when the results of Weismann's researches were extinguishing the Lamarckian element which had been added to the Darwin-Wallace theory, I heard Lord Balfour say that to him, as a student of philosophy, the new teachings on the scope of heredity were more interesting than the old. Again, in 1927, a few months before his eightieth birthday and before he began to dictate the charming

[59] *Handbuch der Entomologie.*

[60] *Proc. Ent. Soc. Lond.*, p. lx., 1913. As regards chance likeness in form, Bates wrote in his great paper (p. 514 n.): "Some orders of insects contain an almost infinite variety of forms, and it will not be wonderful, therefore, if species here and there be found to resemble each other, although inhabiting opposite parts of the earth, and belonging to widely different families. Such analogies are accidental, and can have nothing at all to do with the evidently intentional system of resemblances, carried on from place to place, which I have discussed."

[61] *Essays on Evolution*, p. 233 n.

[62] *Proc. Ent. Soc. London.*, p. xcv., 1925–26.

[63] *Ibid.*, p. 508.

[64] *Ent. Monthly Mag.*, p. 177, 1913; *Proc. Roy. Soc.*, B., vol. cii., p. 327, 1928. All the other observations are recorded, with full references to earlier publications, in the *Trans.* or *Proc. Ent. Soc. Lond.*

[65] *Proc. Roy. Soc.* B., vol. 107, p. viii., 1930.

but too brief "Chapters of an Autobiography," he said that, looking back, he was impressed by the fact that nothing suggested in later years had replaced or modified the Darwinian theory of evolution.

And now in conclusion, speaking at the close of the second half-century of our society's life, and speaking as one who owes more than he can express to the kindness and help received at these meetings, I can not do better than remind you of prophetic words spoken at Oxford in 1832. Professor Adam Sedgwick, responding after his nomination as president at Cambridge in the following year, said that the work of the association at the meeting which had just been held could not but tend "to engender mutual friendship, mutual forbearance, mutual kindness and confidence"; and, for the future, "he looked forward with full assurance to the happy results of this union between men of similar sentiments and similar pursuits, who possess one common object—the improvement of mankind by the promotion of truth."

SCIENTIFIC EVENTS

THE INTERNATIONAL GEOLOGICAL EXPEDITION

AN international expedition under the sponsorship of Princeton University will make a concentrated study next winter of the geological structure of the West Indies, it was recently announced by Professor Richard M. Field, of Princeton University, director of the expedition.

The U. S. Navy is cooperating in the project and will place a submarine at the disposal of the expedition. The submarine will assist the investigators in obtaining as nearly stable conditions as possible for under-water gravity tests. The U. S. Coast and Geodetic Survey, the Royal Society of Great Britain and the National Research Council are other national organizations cooperating with Princeton University in the expedition.

The data which the expedition will obtain during its ten weeks' stay in the West Indies are expected not only to aid in determining the relative stability of the islands and the manner in which they have been formed, but also to throw further light on the origin of the major inequalities on the earth's surface, particularly the origin of folding and faulted mountain ranges.

About 5,000 miles of submarine profiles will be measured and 30 or 40 gravity-at-sea stations will be established. The submarine will be used in this phase of the expedition's work. The new "three-pendulum" apparatus, which is the latest device for determining the difference in gravity at different points on the surface of the earth, will be used in the work of "weighing" the islands and the "deeps." The data to be obtained may also be of assistance in determining the location of earthquakes.

Land gravity stations will be established by the U. S. Coast and Geodetic Survey with the help of Mr. Hugh Matheson, of Miami, Florida. The plans also call for the drilling of bore-holes to determine the structure of the islands.

Soundings and charts which the expedition will make will be of assistance to ships navigating in the West Indian waters in the future. The expedition will begin work early in February.

The personnel of the advisory staff and of the expedition is as follows:

Navigation: Rear-Admiral W. R. Gherardi, chief hydrographer, U. S. Navy; Hugh Matheson, Miami, Florida.

Geophysics: Rear-Admiral Gherardi; Dr. William Bowie, chief, U. S. Geodetic Survey; Dr. F. Vening Meinesz, Geodetic Survey of the Netherlands; Dr. F. E. Wright, U. S. Geophysical Laboratory; George W. Littlehales, hydrographic department, U. S. Navy.

Tectonics or mountain building: Dr. Arthur Keith, U. S. Geological Survey; Professor E. B. Bailey, chairman of the department of geology of the University of Glasgow; Professor Owen Thomas Jones, chairman of the department of geology, Trinity College, Cambridge, England; Professor R. T. Chamberlin, chairman of the department of geology of the University of Chicago; Professor Walter H. Bucher, professor of geology at the University of Cincinnati; Professor W. T. Thom, associate professor of geology at Princeton University, senior geologist, U. S. Geological Survey, and chairman of the petroleum committee of the National Research Council.

Oceanology: Professor Edwin Grant Conklin, chairman of the department of biology of Princeton University; Dr. Charles Fish, director of the Buffalo Museum of Science; Professor Ulric Dahlgren, professor of biology at Princeton University.

Sedimentation: Professor Alexander Hamilton Phillips, chairman of the department of geology of Princeton University; Professor Richard M. Field, associate professor of geology at Princeton University and director of the International Summer School of Geology; Ernest Dixon, of the Geological Survey of Great Britain; Maurice Black, fellow of Trinity College, Cambridge, England; Dr. Edward M. Kindle, chief of the division of paleontology, Geological Survey of Canada; Professor John Sandidge, of the department of geology of Princeton University.

Marine Bacteriology: Dr. Selman A. Waksman, microbiologist, State of New Jersey Agricultural Experimental Station, and associate professor of microbiology at Rutgers University.

INDUSTRIAL RESEARCH IN THE NATION'S INDUSTRIES

A TOUR of research laboratories this fall by one hundred business men and bankers, the purpose of which is to show members of the party what the nation's industries, small and large, are doing in the field of industrial research, has been announced by Professor Dugald C. Jackson, head of the electrical engineering department of Massachusetts Institute of Technology, and chairman of the division of engineering and industrial research of the National Research Council, the sponsors of the tour.

The program of the tour, which is scheduled to take place from October 5 to 14, inclusive, provides for visits to fourteen laboratories, in which research activities by a large variety of industries will be disclosed. Members of the party will have an opportunity to see the latest developments in photography, light, color, electronics, x-rays, industrial chemistry in many phases, rubber research, dirigible construction and other aspects of aviation, motors, electrical apparatus, leather-tanning, research in metals and fuels, etc.

The tour started from New York City, where the party took one of the Eastern Steamship Line boats for Boston. The remainder of the trip was by special train. On October 6, a visit was made in the morning to the Massachusetts Institute of Technology; in the afternoon, visits to the following organizations were optional: Arthur D. Little, Inc.; Dewey and Almy Chemical Company, and the New England Confectionery Company, all of Cambridge; the United Drug Company and the Thompson and Lichtner Company, Inc., both of Boston. Tour activities in and around Boston were conducted with the New England Council as hosts.

During the remainder of the trip the following are among the organizations to be visited: On October 7, the Eastman Kodak Company, Rochester, N. Y.; on October 8, the Goodyear Tire and Rubber Company, Akron, Ohio, and Nela Park, Cleveland; on October 9, the Ford Motor Company, Dearborn, Michigan; on October 10, Tanners Council of America and General Foods Corporation, both at the University of Cincinnati; on October 12, the Battelle Memorial Institute, Columbus, Ohio; on October 13, the Westinghouse Electric and Manufacturing Company, Pittsburgh. On October 14, the party will return to New York City.

Details of the tour have been worked out by Mr. Maurice Holland, director of the division of engineering and industrial research of the National Research Council, who had charge of the arrangements of a similar tour under the same auspices last October, when the following nine laboratories were visited: The Bell Telephone Laboratories, New York City; the General Electric Company, Schenectady; the General Motors Corporation, Detroit; the Material Division, Air Corps, U. S. Army, Wright Field near Dayton; the American Rolling Mill Company, Middletown, Ohio; the Aluminum Company of America and Mellon Institute of Industrial Research, both of Pittsburgh; the U. S. Bureau of Standards and the National Canners Association, both of Washington.

THE NEW ENGINEERING BUILDING AT THE UNIVERSITY OF WISCONSIN

THE new mechanical engineering building erected at the University of Wisconsin during the past year at an approximate cost of $577,000 was used for the first time in September.

Several hundred tons of ponderous steam and gas engine machinery, some of which has been in use in the training of a generation of University of Wisconsin engineering students, was moved into the new building during the summer months from the old engineering building on the upper campus, under the direction of Professor J. M. Dorrans, assistant professor of mechanical practice and superintendent of the machine shops.

Located at the north end of Camp Randall, the new engineering building is constructed of Madison sandstone, with a frontage of 238 feet and with two wings, each 210 feet long. Built in U-shape, it is three stories high, and contains a mechanical laboratory two stories in height, thus giving necessary space for tall equipment. Besides the general machine laboratories, containing 67 huge machines, and the steam and gas engine laboratory, the building contains various shops, departments, offices, classrooms and drafting rooms.

The new building, which was dedicated during the latter part of June, has been designated as the third milestone in the history of the Wisconsin College of Engineering by Dean F. E. Turneaure, who joined the engineering staff at the university thirty-nine years ago. The first two milestones, according to Dean Turneaure, were the expansion of the engineering teaching staff in the fall of 1891 and the completion of the present College of Engineering Building in 1900; the new building marks the first major addition to the space assigned to the engineering college in more than thirty years.

In the new building is a large picture of Colonel Charles A. Lindbergh, hanging on the wall of the front hall of the new building, and directly opposite it, suspended by cable from the ceiling, is a large navy biplane, which was given to the college by the navy some time ago. The picture, portraying Colonel Lindbergh in flying togs, is approximately eight feet

wide and ten feet long, and was painted for the building by painters at the service building of the university a year or so ago. It recalls the fact that Colonel Lindbergh was enrolled in the college of engineering at the University of Wisconsin some years ago.

THE CANAL ZONE EXPERIMENT GARDENS

WITH the slow but constant increase in the development of agriculture in the Republic of Panama, there should be a considerable amount of interest in the "Annual Report of the Canal Zone Experiment Gardens," according to the *Panama Star and Herald*, an official publication of the Panama Canal.

The experiment gardens were established several years ago, and prior to that time practically nothing had been done in the matter of the scientific development of agriculture on the Isthmus. The gardens have been operated on a most modest scale and emphasis has been laid on the development of trees and vines, fruits and flowers, as well as the so-called economic plants. As to the relatively unimportant matter of plants and flowers, the situation was well summed up by Dr. Paul C. Standley, who said, in speaking of flora of the Canal Zone: "There is probably no region of Central America which exhibits so mediocre a selection of horticultural or ornamental plants as does this part of Panama. Scarcely one garden plant of any special interest is seen about Panama City, all those planted being the most ordinary and wide-spread tropical ornamentals."

All that has been changed and the experiment gardens have provided hundreds of new varieties gathered from many remote parts of the world.

As an example of the work being done, reference may be made to the introduction, propagation and dissemination of the varieties of sugar cane. The report points out that the sugar industry in Panama is at present suffering much from the mosaic disease and other pests, and that there is a need of varieties of cane resistant to this disease and also of higher sugar-yielding capacity.

To meet this need the gardens introduced many varieties of cane, including a number that have proved satisfactory in other countries. During the last year sample lots for testing under plantation conditions have been distributed without charge to cane growers in the republic. New varieties are constantly being received and developed. The same work is being done with rice—great quantities of which are imported into Panama.

While emphasis is placed on the development of those things which give most promise of producing economic results, the ornamental plants and trees are not being overlooked, and many new varieties, hitherto unknown to the Isthmus, are being constantly introduced and developed. Mention might also be made of the strides which have been made in the scientific development of the avocado, the mango, the pineapple, the banana and even the fig.

Just recently Governor Roosevelt, of Porto Rico, pointed out the great advantages which would result from the establishment by the government of the United States of extensive agricultural experiment stations in the tropics. Both the necessity and the advantages of such outlying stations can not be overestimated.

The valuable work which has been started at the Canal Zone Experiment Gardens at Summit might well be conducted under the U. S. Department of Agriculture. The cost of operating the gardens would not be great and in all probability the expenditure of a sum not greater than $75,000 a year would produce results of incalculable value to the agricultural interests of this part of the world and would be a service worth many times its cost in the good-will engendered.

THE NATIONAL ARBORETUM

As an initial step in the development of the proposed national arboretum, the marshland along the Anacostia River in the outskirts of Washington, two and a half miles from Capitol Hill, is being drained by army engineers. With the appropriation of $300,000, which the Congress set aside for the project in 1927, a tract of 268 acres of land has been purchased. The physiography of the area ranges from the water gardens of Kenilworth to the wooded heights of the Hamilton and Hickory Hill tracts, which will be included in the arboretum. The two bodies of land afford the diversity of soil and physiography needed for many types of plants.

The U. S. Department of Agriculture has hitherto been unprovided with a field laboratory of the proper size for experiments with the plant life of the country and horticulturists have supported its efforts to obtain one. A garden will be established to preserve specimens of plant life which come to the Agricultural Department from all parts of the world.

The arboretum will have laboratory facilities as well as museum characteristics. Cultivated and wild plants growing side by side, in the same type of soil and in the same climate, will be studied to aid the breeding of more valuable species.

Horticulturists will have an opportunity to carry on research in developing desirable types of plants with superior qualities from available stock in different localities, and through experimentation it may be possible to eliminate many diseases which now threaten our forests in many sections of the country, such as maple wilt, elm-leaf diseases, chestnut blight and many others.

SCIENTIFIC NOTES AND NEWS

DR. WILLIAM H. WELCH, professor of the history of medicine at the Johns Hopkins University, has been made an honorary member of the International Neurological Congress. Other honorary members elected were: Professor M. Allen Starr, of Columbia University; Professor Ivan P. Pavlov, of the University of Leningrad; Professor J. Wagner-Jauregg, of the University of Vienna; Professor Pierre Marie and Dr. J. Babinski, of the University of Paris; Professor Gabriel Anton, of the University of Halle, and Professor Eugenio Tanzi, of the University of Florence.

DR. WITMER STONE, vice-president of the Academy of Natural Sciences of Philadelphia and curator of its department of vertebrate zoology, has been awarded the Otto Hermann medal of the Hungarian Ornithological Society—the highest honor conferred by that organization—in recognition of his "outstanding work in the science of ornithology."

DR. STEPHEN H. LANGDON, professor of Assyriology at Oxford University, and Dr. Ludwig Diels, director of the Botanical Garden and Museum of Berlin-Dahlem, have been elected corresponding members of the Field Museum of Natural History by the board of trustees, in recognition of their eminent services to the museum.

DR. LAUGE KOCH, Danish explorer, has received the Charles P. Daly Medal for 1930 from the American Geographical Society.

PROFESSOR CARL NEUBERG, director of the Kaiser Wilhelm Institute for Biochemistry, has been awarded the Pasteur and Leblanc Medals, and the Pasteur Commemoration plaquette.

DR. WILLIAM A. EVANS, radiological specialist of Detroit, has been elected president-elect of the American Roentgen Ray Society, at the thirty-second annual meeting, held at the Chalfonte-Haddon Hall Hotel on September 24. Other officers elected were: Dr. B. R. Kirklin, of Rochester, Minn., and Dr. Ross Golden, of New York, vice-presidents; Dr. E. P. Pendergrass, of Philadelphia, secretary, and Dr. Edward L. Jenkinson, of Chicago, treasurer.

AT the annual meeting of the Geographical Society of Philadelphia Mr. Henry G. Bryant was elected president, a position he has repeatedly filled since 1894. Subsequently the board of directors appointed Dr. Lester E. Klimm, assistant professor of geography, University of Pennsylvania, as part-time executive secretary and acting editor of the bulletin of the society.

DR. CHARLES FRANKLIN BROOKS, professor of meteorology and climatology at Clark University, will become, in February, A. Lawrence Rotch professor of meteorology at Harvard in succession to Professor Alexander G. McAdie, who has become Rotch professor and director, emeritus. Until February Dr. Brooks will spend half of his time in Cambridge and half in Worcester.

DR. E. D. BALL has resigned as dean of the college of agriculture and director of the agricultural experiment station of the University of Arizona, to accept the position of professor of zoology and zoologist of the experiment station, in order to be able to devote more time to research.

THOSE who are new on the faculty at the Case School of Applied Science include: Mr. Ervin W. McCullough, consulting engineer with the Republic Creosoting Company, who has been made professor of mining engineering, and Dr. P. E. Hemke, who has been made associate professor of mechanics.

NEW appointments at the University of Minnesota include the following as assistant professors: Mr. Ira D. Beals, in architecture; Mr. Russell E. Gibbs, in steam engineering; Mr. James J. Ryan, in machine design, and Mr. Michael A. Sadowsky, in mathematics and mechanics. Professor George H. Montillon was promoted from associate professor to professor of chemical engineering. Mr. Chester A. Hughes and Mr. Joseph A. Wise were promoted to associate professors of civil engineering.

THE following appointments to the faculty of the school of engineering of the Pennsylvania State College are announced: Dr. L. F. Pilcher, formerly vice dean of the faculty in the college of arts of the University of Pennsylvania, who has returned after an absence of one year, will take charge of architectural design; Dr. Clarence Hammond Kent, formerly head of the department of mechanical engineering at the University of Arkansas, has been appointed associate professor of mechanical engineering; Mr. P. X. Rice becomes assistant professor of electrical engineering; Mr. P. P. Henshall returns as assistant professor of industrial engineering. Instructors appointed are: Mr. Clifford B. Holt, in electrical engineering; Mr. J. O. P. Hummel, in industrial engineering; Mr. R. C. Gersen, in engineering drawing; Mr. William H. Peters, and Mr. J. S. Doolittle, in mechanical engineering.

DR. CHARLES S. ROBINSON, in charge of the chemical division of the Michigan Experimental Station, has been elected professor of biochemistry in the Vanderbilt University School of Medicine, replacing Dr. Glenn E. Cullen, who has resigned to become

director of laboratories at the Institute of Pediatric Research of the University of Cincinnati Medical School.

DR. GEORGE A. DICK has been appointed dean of the school of veterinary medicine at the University of Pennsylvania. He succeeds the late Dr. Harold E. Bemis, who died in April. Promotions announced by President Thomas S. Gates are as follows: Dr. James A. Shohat has been made assistant professor of mathematics in the college; in the school of medicine Dr. Stuart Mudd has been appointed associate professor of bacteriology. Assistant professors are: Dr. Donald M. Pillsbury, in dermatology; Dr. Roy G. Williams, in anatomy; Dr. Joseph Stokes, Jr., who also will hold the William H. Bennett memorial chair of pediatrics. Professors in the graduate school of medicine are: Dr. Ralph Pemberton, in medicine, and Dr. William D. Stroud, in cardiology. Assistant professors are: Dr. Edward W. Beach, in anesthesia, and Dr. Truman G. Schnabel, in medicine. In the Towne Scientific School, Dr. Ernest C. Wagner has been appointed professor, and in the Moore School of Electrical Engineering, Mr. Charles DeV. Fawcett has been made professor of engineering. In the school of medicine Dr. Edward A. Strecker, formerly a member of the faculty of Jefferson Medical College, has been appointed professor of psychiatry. The graduate school of medicine has added to its faculty Dr. Clarence R. O'Crowley, of Newark. Dr. Arthur B. Gabel, of Seattle, has been named assistant professor of operative dentistry in the school of dentistry.

DR. HARRY BECKETT LANG, of the staff of Willard State Hospital, Willard, N. Y., has been appointed clinical director at Marcy State Hospital, Marcy, N. Y.

THE U. S. Bureau of Fisheries announces a change in the directorship of the U. S. Fisheries Biological Station at Beaufort, N. C. Dr. S. F. Hildebrand, who has occupied that position for the past six years, has been transferred to Washington as senior ichthyologist of the bureau, where he will continue his studies of fishes with the superior facilities of the library and museum collections available in that city. The position of superintendent and director of the Beaufort station has been filled by the appointment of Dr. Herbert F. Prytherch. Laboratory facilities at the station will be made available for independent investigators in hydrobiology throughout the year, and the station will serve as headquarters for Dr. Prytherch's theoretical and practical studies on the biology of the oyster and the development of oyster culture in the South Atlantic states. As a result of examinations held by the U. S. Civil Service Commission early in the summer, the Bureau of Fisheries announces the appointment of Mr. William C. Herrington as aquatic biologist to take charge of a major investigation of the haddock fishery of the North Atlantic. Dr. Frederic F. Fish has been appointed associate aquatic biologist for investigations in fish pathology. Dr. Paul R. Needham, formerly of the University of Rochester, has been appointed as associate aquatic biologist for investigations in hydrobiology and aquiculture. Dr. A. S. Hazzard has been appointed to undertake extensive duties as associate aquatic biologist in charge of fish cultural and stocking policies in the national parks of the Rocky Mountain region with headquarters at Salt Lake City, Utah.

DR. ROBERT CUNNINGHAM MILLER, of the University of Washington, will return to Seattle this month after two years' leave spent as visiting professor of zoology at Lingnan University, Canton, China. During the summer he has been collecting marine wood-boring organisms along the coasts of South and East Africa, also conducting certain investigations for the University of Washington Oceanographic Laboratories while at sea.

PROFESSOR HOMER C. WILL returns to Juniata College as head of the biology department after a two year's leave of absence for graduate study in the University of Michigan and the University of Pittsburgh.

PROFESSOR MARSHALL P. CRAM, professor of chemistry at Bowdoin College, has been granted a sabbatical leave of absence for the coming year.

ON the recommendation of the secretary of state for Scotland, Dr. John Glaister, Jr., professor of forensic medicine in the University of Egypt at Cairo, has been appointed to the chair of forensic medicine in the University of Glasgow. He is the son of the present occupant of the chair.

DR. ARTHUR H. COMPTON, professor of physics at the University of Chicago, who recently returned to the university from an expedition in the Rocky Mountains, where he conducted a series of experiments on the cosmic rays, has left for Europe with Mrs. Compton. He will attend the International Physics Conference to be held at Rome from October 11 to 19, under the auspices of the Volta Foundation. At the conclusion of the conference he will go to Zurich to conduct further experiments with cosmic rays, to determine the difference in intensity in the Alps as compared with the Rocky Mountains.

DR. W. W. SWINGLE, of Princeton University, will deliver the first Harvey Society Lecture at the New York Academy of Medicine, on Thursday, October 15. His subject will be "The Hormone of the Suprarenal Cortex."

THE George Fisher Baker non-resident lecturer in chemistry at Cornell University for the present university term is Professor Cecil Henry Desch, who has held the professorship of metallurgy in the University of Sheffield up to last June, but who, on his return to England next February, will enter upon the position of superintendent of the metallurgical department at the National Physical Laboratory in Teddington. He is the twelfth holder of the non-resident lectureship founded by George Fisher Baker in 1925, which in accordance with the terms of the foundation is filled in succession by men eminent in chemistry or in some related branch of science.

DR. A. C. BAKER, senior entomologist and in charge of tropical and subtropical plant insect investigations, of the U. S. Bureau of Entomology, left on September 25 for Mexico City, where he will study the Mexican fruit fly and related species. Dr. C. L. Marlatt, chief of the bureau, in announcing Dr. Baker's transfer to Mexico City, explained that citrus plantings in the Lower Rio Grande Valley have expanded rapidly and a few adult flies have appeared in this region.

THE *British Medical Journal* reports that an international Federation of Societies of Tropical Medicine and Hygiene has been constituted, under the presidency of Professor C. Achard, by the association of leading authorities on tropical medicine from twenty countries. At the invitation of the editorial committee of the *Revue pratique des Maladies des Pays Chauds,* various societies will exchange views on different subjects in order to bring into being a legal constitution for the international federation.

Nature reports that a meeting was recently held of the subcommittee on symbols, units and nomenclature used in physics, appointed by the International Union of Physics. Sir Richard Glazebrook was appointed chairman of the committee. Professor Kennelly, as chairman of the section of the advisory committee of the international electro-technical commission dealing with electrical and magnetic magnitudes and units, wrote, directing attention to the meeting of his committee in London on September 18, and inviting members of the committee of the International Union of Physics to attend. This invitation was accepted, and the meeting of the subcommittee on symbols, units and nomenclature shortly afterwards continued the discussion commenced at Brussels.

AT the close of the second International Hospital Congress, which met in Vienna from June 8 to 14, the representatives of the 41 countries participating in the congress voted unanimously to organize an International Hospital Association. The purpose of the association is to bring about an international exchange of opinion and international cooperation in all problems and in all fields of hospital work and in all relationships, economic, sociological and hygienic. The association is composed of two classes of members—ordinary members, consisting of national hospital associations, and associate members.

THE U. S. Civil Service Commission announces that applications for the positions of associate and assistant metallurgists (optional subjects—ferrous metallurgy, non-ferrous metallurgy, physical metallurgy and ore dressing) must be on file with the commission at Washington, D. C., not later than December 30, 1931, except that the commission reserves the right to issue subsequent notice closing the receipt of applications before that date. The examinations are to fill vacancies in the departmental and field services. The entrance salaries for associate metallurgist range from $3,200 to $3,800 a year, and for assistant metallurgist from $2,600 to $3,200 a year. Competitors will not be required to report for examination at any place, but will be rated on their education, training, experience and fitness, and on a thesis, reports or published writings. Applicants must have been graduated with a bachelor's degree from an institution of recognized standing, with major work in chemistry, physics or metallurgy. Certain specified experience or postgraduate education is also required. Full information may be obtained from the secretary of the U. S. Civil Service Board of Examiners at the post office or customhouse in any city or from the U. S. Civil Service Commission, Washington, D. C.

PLANS have been filed for erecting a six-story addition to a new building occupied by the New York Academy of Medicine and opened in 1926, at the southeast corner of Fifth Avenue and 103rd Street, New York. The cost will be $450,000. Construction will not begin until the academy has raised an additional $95,000. The annex will be used for offices, committee rooms, for the exhibition and storage of books on historical medicine and library services. The old building of the academy, constructed in 1888, at 15 to 21 West 43rd Street, was sold in 1925, and is now being demolished.

A LABORATORY of anthropology, established to study the origin and development of the Americas, was formally opened in Santa Fe, New Mexico, on September 1. From this laboratory, which has been sponsored by John D. Rockefeller, Jr., expeditions in North, South and Central America will be directed. Regardless of their organization affiliation, scientific men may work individually or in collaboration with each other in anthropological research. The first unit is a building of pueblo architecture recently completed at a cost of $144,000. Dr. A. V. Kidder is chairman of the board of directors.

THE Shippee-Johnson Peruvian Expedition, which sailed from New York on December 6, 1930, to carry out, with the endorsement of the American Geographical Society, a program of aerial mapping and other photographic work from the air in various parts of Peru, returned on September 7. In spite of numerous delays occasioned by the unstable conditions in Peru the expedition was able to accomplish even more than had been planned in its tentative program. In addition to the mapping, from elevations of over 25,000 feet, of the deep valley of the Colca River some seventy miles north of Arequipa—the primary object of the expedition—a land party spent two weeks in the valley studying its people, the history of the little-known agricultural communities of the valley floor, their methods of agriculture, etc. Archeologists as well as geographers will be interested to know that the expedition mapped the whole of the Chimú Valley and the ruins of Pachacamac and discovered and photographed, a short distance north of Chimbote, the remains of what appears to be a great defensive wall believed by Peruvian archeologists to be a part of the Chimú fortifications against the Inca invaders. Besides the aerial mapping, hundreds of aerial photographs were taken and a large amount of motion picture film exposed throughout the coastal region of Peru and the western border of the Andes. Several flights from Lima over the western range of the Andes to Huancayo resulted in a series of remarkable photographs of much geological and physiographic interest. A report on the work of the expedition will appear in a forthcoming number of the *Geographical Review*.

THE *Pelican*, a ninety-foot motor vessel of the U. S. Fisheries Service, loaned to the International Passamaquoddy Fisheries Commission by the United States Government, has just arrived in St. Andrews. Oceanographic equipment will be installed there and it is expected that within a few days active field work will begin. A second vessel, the *Edward E. Prince*, loaned to the commission by the Biological Board of Canada, has already been outfitted. The *Pelican* was constructed during the past year at Newport News, Virginia, for the U. S. Fisheries Service at Boothbay Harbor, Maine. The captain, George Greenleaf, has had considerable experience in oceanographic work, having formerly been associated with Dr. Fish in investigations for several years in the Gulf of Maine and for two years in Lake Erie, where a cooperative survey was carried on in 1929 and 1930. For the remainder of the summer season the two vessels will base at the Atlantic Biological Station, where headquarters for the commission have been established.

A LOAN exhibition of modern British optical instruments took place in the Science Museum, South Kensington, England, at the time of the British Association centenary meeting, and apparatus was loaned by a number of the leading manufacturers in Great Britain. The display will be on view up to the end of October in the optical instrument gallery, and popular demonstrations will take place at intervals. About 100 exhibits have been provisionally selected, including binoculars, rangefinders, photographic and microscopic objectives, projection-microscopes and surveying instruments. Aerial cameras, microphotometers, spectrographs and a cinema projector are among the developments of optical technique to be illustrated, and a strain-viewer will demonstrate the differences and flaws to be observed in various everyday objects of glass.

PRELIMINARY plans for a new entomology building to be built at a cost of $150,000 for the University of California Experiment Station at Riverside were virtually brought to completion, following a recent conference of the director, Dr. L. D. Batchelor, members of the staff and R. A. Weaver, of the department of buildings and grounds at Berkeley. The new building will be L shaped in floor plan, 100 feet on the longest side and 70 on the other. The major part of the structure will be two stories in height with a basement and attic. There will probably be a greenhouse in the attic and rooms for testing large power spray rigs in the basement. Other facilities included in the plans are rooms for fumigation experiments, spraying investigations, taxonomical and physiological studies, etc. Several of the rooms will be equipped for carrying on experiments requiring controlled environment with constant temperature and humidity. The site selected for the new building is a short distance northeast of the main building of the experiment station, close to the recently completed insectary, the facilities of which it will supplement.

DISCUSSION

A NEW MATHEMATICAL REVIEW

FOR the first time in the history of mathematics there was inaugurated in April of the current year a monthly periodical exclusively devoted to the prompt review of mathematical publications or to the preliminary announcements of results which are expected to be published later *in extenso* in the technical journals. It appears under the heading *Zentralblatt für Mathematik und ihre Grenzgebiete*, and the reviews include, besides pure mathematics, such subjects bor-

dering thereon as theoretical physics, astrophysics and geophysics. The editor-in-chief is O. Neugebauer, of Göttingen, who is well known as a mathematical historian, and the publisher is Julius Springer, Berlin.

Judging from the first five numbers, which cover 384 pages, the reviews are unusually reliable and the publication promises to be very useful to those who try to keep in touch with the latest developments in the fields concerned. While it covers to a large extent the same field as has been covered acceptably for more than half a century by the "Jahrbuch über die Fortschritte der Mathematik" its more prompt and more frequent appearance tend to make it a welcome supplement thereto. It seems to have exercised already a wholesome influence on this annual since the parts of the latter have recently appeared much more promptly than theretofore.

In addition to these two reviews, which are published in Germany, the mathematical public has had the advantage since 1893 of another very useful periodical devoted to reports on recent publications in its field and appearing in various countries. This periodical is published under the auspices of the Mathematical Society of Amsterdam and appears under the title *Revue Semestrielle des Publications Mathématiques*. A very useful supplement to this periodical appears in the form of supplementary volumes each covering a period of five years. The main novel feature of the new periodical noted above is therefore the rendering of prompter service to the mathematical student of to-day.

G. A. MILLER

UNIVERSITY OF ILLINOIS

ON THE IMPROVEMENT OF THE DICTIONARY

DICTIONARIES and all other word-tabulations are valuable in proportion to their comprehensiveness and to their ease of use. Assume that we have a comprehensive table. How much it is used will depend mainly on how much trouble its use involves, or how fatiguing are the operations of the human eye and hand. When I contemplate the fact that a certain German-English dictionary has no less than 15 two-column pages of words beginning with "sch" I am tempted to forego the pleasure of adding to my knowledge the English equivalent of some word in this group.

In looking up such a word as "schmieden" the attention is first focused upon the initial letter and the pages are turned to "s." Time and effort can here be saved if the edges of the pages are so cut that the whole alphabet is seen at a glance with the letters running vertically downward from A to Z along the right-hand edge. The thumb may be placed on "s" and the book opened at nearly the right page. Turning a few pages brings one to "sch." Here the real trouble begins. The mental attention is no longer focused upon "sch" but upon "mieden." The eye strives to find these letters. However instead of making them prominent and as easy to find as the first letter of a word the printer has artfully concealed them behind "sch." The eye must search through 15 pages looking always for the fourth letter of the word, then for the fifth letter, etc. There are no heavy face type, no italics, no capitals to aid in this search. It is veritably a game of hide and seek, and after a dozen such attempts the mind is fatigued, some of the words are not found, and the dictionary is thrown down in irritation. How much more convenient it would be with the elimination of all syllables or even all letters common to the series, after they have once been given. Such is the present day practice in tables of numbers. Common figures are eliminated. The following tables show: 1, an old number table; 2, the typical present day arrangement; 3, the usual way of listing words; 4, the proposed system.

Table 1		Table 2		Table 3	Table 4
N	log N	N	log N	Usual system	Proposed system
150	17609	151	17609		
151	17898	2	898	schmelz	schMELZ
152	18184	3	18184	schmelzarbeit	ARBEIT
153	18469	4	469	schmelzbar	BAR
154	18752	4	752	schmelzhafen	HAFEN
155	19033	5	19033	schmelzwerk	WERK
156	19312	6	312	schmer	schMER
157	19590	7	590	schmergel	GEL
158	19866	8	866	schmerhaft	HAFT
159	20140	9	20140	schmerz	Z
160	20411	160	411	schmetterling	schMETTERLING
				schmettern	N
				schmetterschlag	SCHLAG
				schmidt	schMIDT
				schmied	schMIED
				schmiedbar	BAR
				schmiedbarkeit	BARKEIT
				schmiede	E
				schmiedearbeit	schmiedeARBEIT
				schmiedeeisen	EISEN
				schmiedeeisern	EISERN
				schmiedefeuer	FEUER
				schmiedeherd	HERD
				schmiedeisen	schmiedEISEN
				schmiedeisern	EISERN
				schmieden	EN
				schmiegen	schMIEGEN
				schmiegsam	SAM

I think, so far as is possible, that it is better to introduce whole new syllables rather than each new letter by capitals, *e.g.*, by schMIDT, schMIED, rather than schmIDT, schmiED, because the latter seems to distort the apparent pronunciation of the words. Speed and facility in the use of number tables have been enormously enhanced by the modern arrangement, and I believe the same advantages will be gained by modernizing the old "Wörterbuch." In regard to cost, I have the opinion of an experienced professional book-printer that the cost of typesetting will be less for the proposed system. Many printers

maintain the practice of capitalizing the initial letter of all German nouns. This could not be done in a table such as Table 4, but the nouns and their genders may be indicated by the italicized letters *m, f,* or *n* immediately following.

"Sch" is not the only offending prefix. The same book has 7 pages of words beginning in "ab," 4 pages "auf," 7 pages "be," 2 pages "durch," 4 pages "ein," 1 page "gesch," 3 pages "uber," 6 pages "un," 10 pages "ver," 3 pages "vor," etc. This is not a defect peculiar to this book, nor to the German language which Mark Twain reviled so heartily in his story of the "Hottentotenmutterattentäterbeutelrattenlattengitterwetterkotter." On the other hand all dictionaries including those of English words suffer the same shortcoming. So far as is possible let common words and syllables be omitted, and the distinguishing letters be printed in bold face or capitals, and reading such books will become a pleasure. Thus the chief obstacle to foreign language reading will disappear, wasted mental effort and eye-strain will be reduced, and the publishers will gratify their ambition to make two dictionaries flourish where one languished before.

NELSON W. TAYLOR

UNIVERSITY OF MINNESOTA

TERRACES IN THE CONNECTICUT VALLEY

THE terraces of the Connecticut Valley in the region of Springfield and Hartford, studied at various times by Dana, Emerson, Alden and Fairchild and more recently investigated by the writer,[1] continue to offer new material for discussion. The writer considered these features to be prevailingly horizontal and chiefly of lacustrine origin, only minor individuals being overlain by fluviatile deposits with profiles inclined down-valley. Recently the writer, assisted by R. M. Logie, ran a level line with plane-table and stadia rod on the terrace at approximately 60 feet, extending with a few gaps through a distance of 22 miles along the eastern side of the river between Glastonbury, Connecticut, and the Massachusetts state line. This terrace was found to be essentially horizontal, with a maximum relief of 18 feet, the highest parts being arranged opposite the mouths of two tributary streams in such a way as to suggest local fans built above the general surface of the terrace.

Prior to this time Messrs. Hitchcock and Wood, of the American Geographical Society, at the suggestion of Professor Douglas Johnson,[2] ran a more extensive series of Wye-level lines on several conspicuous terraces on both sides of the river between Windsor, Connecticut, and the Massachusetts line, and on extensive terraces in the Quinnipiac Valley. Profiles constructed from these level lines show the terrace tops to be broadly irregular with inclinations generally down-valley. Some of the profiles have distinct breaks at the levels at which the writer has described terrace surfaces; in a number of others the down-valley slope continues unbroken through these levels. These profiles appear to the writer to indicate fluviatile deposition under the control of several base-levels and the writer considers that the terraces they represent consist of fluviatile material overlying lake deposits, while admitting that the fluviatile material is more widespread than he had formerly believed.

During a recent two-day field conference with the writer Professor Johnson pointed out, on some of the broad lower terraces east of the river, shallow curved channels lying generally against eroded faces of the next higher terraces. These resemble the channels found on many flood-plains and appear to indicate that the surfaces of the terraces on which they occur have been fashioned by streams and that the faces, previously interpreted by the writer as constructional, are chiefly erosional, whatever their original character may have been. The channels were not recognized as systematic features by the writer until Professor Johnson called attention to them.

Sections exposed in sand and gravel pits in these broad lower terraces exhibit current-bedding. Some sections show varved clays and silts. A few exposures show sections of what the writer has described as foreset beds exposed through thicknesses of a few feet, with their bases concealed. Consideration of sections such as these raises a question as to the difference to be expected between deposits made by shallow aggrading streams, and deposits made in narrow lakes strongly affected by currents. Perhaps the only positive criterion for stream deposits in such a comparison is the presence of buried channels visible in exposed sections. One such channel, a few feet in diameter, is exposed in section in the lowest terrace east of the Connecticut River, two miles north of East Windsor Hill, Connecticut. But since deposits built up above the surface levels of lakes by streams that succeed them might be expected to include filled channels, the lower as well as the upper parts of the sections should be examined for these features.

In this connection Professor Johnson has suggested that my published statement that deltaic foresets are the predominant type of stratification in the terrace of Connecticut is misleading. Even the sections showing foresets 15 feet or more in thickness have current-bedded topsets. The writer has included in the

[1] "The Glacial Geology of Connecticut," *Conn. Geol. Survey Bull.* 47, 1930.

[2] Acknowledgment is made for permission to quote the results of this levelling, made as part of a general study of coastal terraces by Professor Johnson under the joint auspices of the American Geographical Society, the Carnegie Institution and Columbia University.

deltaic category, without any intent to mislead, foresets exposed for only a few feet vertically and overlain by current-bedded deposits, in some exposures reaching a considerable thickness, such as are illustrated in Pirsson and Schuchert's "Textbook of Geology," Part I, Fig. 95. 1929 Edition. It is true, however, that current-bedding predominates in a majority of the exposures. The writer has roughly estimated at 25 per cent. the proportion of exposures showing undoubted deltaic structure, whereas Professor Johnson would make the figure much lower.

As far as the lake- or stream-origin of a considerable part of the material composing the terraces in the Connecticut and Quinnipiac valleys is concerned, the presence of varved clays and silts in quantity beneath the sands in the lower terraces seems clearly to indicate lacustrine deposition. In at least two excellent exposures the clays grade upward through varved silts into sands, which in turn exhibit delicate current-bedding. A detailed and specific study of the relation of clays to sands throughout the valley might bring to light important additional data.

The facts indicated by Professor Johnson involve significant reinterpretations in the conclusions reached earlier by the writer, but they do not appear to the writer to preclude the belief that the lower terraces like those at higher elevations were formed while remnants of the last ice sheet still lay in the valley. The discrimination of topographic features whose relief is scarcely perceptible or imperceptible to the eye is admittedly a difficult matter and it is to be hoped that further study may establish more clearly the details of the late-glacial history of the Connecticut Valley.

RICHARD FOSTER FLINT

YALE UNIVERSITY

SCIENTIFIC APPARATUS AND LABORATORY METHODS

A MODIFICATION OF THE OSBORNE-MENDEL SALT MIXTURE

NUTRITION workers who have used the Osborne-Mendel salt mixture[1] in the preparation of experimental diets for rats will agree that this is a bothersome mixture to prepare. Not only must great care be exercised in the addition of the strong acids to the carbonate mixture, but a slow evaporation process is necessary. The removal of the hard mass of dehydrated salts and subsequent grinding present further difficulties.

The authors have developed a salt mixture which, in so far as the metallic elements and mineral acids are concerned, is of the same composition as that of Osborne and Mendel. The mixture is prepared from readily available salts, and requires no evaporation or dehydration. Its content of water of crystallization is slightly higher than that of the Osborne-Mendel mixture. The latter, when prepared according to the original directions (in the proportions required for 10 kilograms of diet), yields about 435 gm. of dried mixture, whereas the equivalent weight of F. R. L. mixture here described is 480.5 gm. Hence in experimental diets prescribing 4.0 per cent. of the Osborne-Mendel salt mixture, 4.4 (or 4.5) per cent. of the F. R. L. salt mixture may be substituted.

Protracted feeding experiments in which the two salt mixtures were fed to divided litters of albino rats, both consecutively and in parallel, showed no differences in growth response.

The composition of the F. R. L. salt mixture is as follows:

Ca Citrate $\cdot 4\,H_2O$		309.67
$Ca(H_2PO_4)_2 \cdot H_2O$		113.25
K_2HPO_4		219.72
KCl		125.29
$NaCl$		77.41
$CaCO_3$		68.90
$MgCO_3$		33.43
$MgSO_4$ (anhydrous)		38.50
Fe Citrate $1\frac{1}{2}\,H_2O$	94.18	
NaF	3.68	
$MnSO_4$	1.17	
$K_2Al_2(SO_4)_4 \cdot 24\,H_2O$	0.67	13.80
KI	0.30	
	100.00	
		1,000.00

The weighed quantities of salts are thoroughly mixed (a McClellan batch mixer is recommended), and then finely ground in a steel mill.

PHILIP B. HAWK
BERNARD L. OSER

FOOD RESEARCH LABORATORIES, INC.,
NEW YORK CITY

A STAIN FOR FIBRIN, GRAM POSITIVE BACTERIA AND BASAL BODIES IN TISSUES

THIS stain is a modification of the Weigert and Gram-Weigert methods for fibrin and gram positive bacteria, respectively.

Tissues are fixed in Zenker's solution (with 5 per cent. acetic acid) or Zenker-formalin (90 cc Zenker's plus 10 cc of 10 per cent. formalin); they are mounted in paraffin and sectioned at 5 μ. After a very light hematoxylin stain they are thoroughly washed in tap

[1] Osborne and Mendel, *J. Biol. Chem.*, 15, 311, 1913; 37, 557, 1919.

water, then dipped into a one half per cent. aqueous eosin (Grubler's *wasserlich*) for a half a minute and washed quickly again. (Washing is done in large volumes of water.) They are then stained in Weigert's aniline methyl violet made up as follows:

SOLUTION 1

Absolute alcohol	33 cc
Aniline oil	9 cc
Methyl violet in excess	

SOLUTION 2

Sat. aqueous solution of methyl violet
(For methyl violet use Grubler's 6B only)

One part of Solution 1 is used to nine parts of Solution 2 for the stain. The two solutions will keep separately, but after mixing, the stain will only last about ten days. It seems to be best about three to eight days after making.

The tissues are stained in the methyl violet about two hours, washed well in tap water and put into Lugol's solution for ten or fifteen minutes, after which they are again washed. Each slide is then blotted thoroughly with filter-paper and subsequently differentiated in a mixture of one part aniline oil to two parts xylol. After washing in several changes of xylol they are mounted in balsam.

The fibrin and gram positive organisms as well as ciliary basal bodies are stained a deep purple; the dark blue nuclei are well differentiated. All outlines of cells can be seen distinctly due to the counter-stain. Blood corpuscles are generally of a pale blue color, though at times they remain pink.

This method has been used particularly in the study of fibrin and of pneumococci (though other gram positive organisms have been stained as successfully) and has proved of special value in the determination of intracellular bacteria.

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SPECIAL ARTICLES

AN OVO-TESTIS IN THE YELLOW PERCH (PERCA FLAVESCENS)

HERMAPHRODITISM occurs fairly regularly in some genera of Teleost fishes (Serranus and Chrysophorous) and teratological hermaphroditism has been observed and described in the Burbot, Carp, Cod, Eel, Top Minnow (Fundulus, Lebistes, Xiphophorus), Stickleback, Herring, Ling, Perch (Perca fluviatilis), Salmon, Sargus, Shad, Whiting, Wrass, Sheepshead, Croaker, Trout and Loach. In the latter cases the testis and ovary are seldom both full sized and normal. Occasionally both gonads are developed to a point which would make functional hermaphroditism possible but usually one gonad is fully formed and normal while the other is partially developed or fragmentary and recognizable only by histological examination. Secondary sex characters such as colors, gonapods, internal structures and behavior are in some instances profoundly affected. In other instances no such modifications are present.

Non-functional hermaphroditism has been observed in the European Perch (Perca fluviatilis) by Halbertsma, Hoek, Ivanzov, Skogman and Chevey, but no record appears in the literature of any similar condition in the American Perch (Perca flavescens).

In the case described here the specimen was discovered by an employee of the Johnson Fish Company, of Green Bay, Wisconsin, in early February and the entire gonad was preserved in alcohol.

The ovarian portion of the gland is 52 mm long and appears to be normal in every respect. It is located in the normal position. An abundance of large ovocytes were plainly visible before dissection and on histological examination the usual arrangement within the ovary of fully formed ovocytes and of undeveloped germ cells was demonstrated. The stroma and tunica were also normal. The testicular mass is somewhat larger than that of a normal testis and is located anterior to the ovary and while it is immediately adjacent to the ovary, it is marked off sharply by texture and color. The testis is abnormal in position, therefore, and superficially appears to be tumorous and misshapen. Several large and many small lobes appear, none of which have the shape of the normal testis. Microscopic sections of the testis, however, show little that could be called abnormal. All lobes are filled with masses of spermatozoa. Each lobe is subdivided by connective tissue septa into cysts just as in the normal testis. At the peripheral margins of the lobes there are flat, lens-shaped cysts of large spermatogonia or primordial germ cells, a relationship which also exists in mature normal testes in February. The only unusual histological feature is the thickening of the walls between some of the lobules and between the testicular and ovarian portions of the gland.

Special attention was given to the region between the ovarian and testicular portions of the gland in order to discover any possible transitional zone. No transition occurs. On both testicular and ovarian sides of the connective tissue junction the line of demarkation is abrupt and there is no evidence of anything but normal tissue.

Since the ovary is normal in every respect it seems likely that the fish was a female and that the abnormally shaped testis arose after the ovary was fully formed. Had the testis developed along with the ovary in the young fish, it might be expected that

FIG. 1. Ovo-testis of Yellow Perch. Irregular testis above, normal ovary below.

neither ovary nor testis would be entirely normal in position or shape.

What stimulation might cause the production of a testis in the presence of a normal ovary it is hardly profitable to guess. It should be noted, however, that nothing in either portion of the gland is so antagonistic to the other as to prohibit the normal germ cell maturation in the other.

Nothing could be made out of the accessory sexual apparatus but if sperm and eggs were provided with a means of escape from the body, the case might be classified as a rare instance of functional (even if teratological) hermaphroditism.

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THE CULTIVATION OF VACCINE AND OTHER VIRUSES IN THE CHORIO-ALLANTOIC MEMBRANE OF CHICK EMBRYOS

THE successful infection of the chorio-allantoic membrane of chick embryos with fowl-pox virus led us to investigate the effect of the inoculation of other viruses upon this apparently highly susceptible tissue. Thus far it has been found that the viruses of vaccinia and herpes simplex infect the membrane notwithstanding the fact that vaccine is only slightly pathogenic for adult fowls, and that repeated attempts to infect adult and young chickens with the virus of herpes simplex by a variety of routes have failed. The susceptibility of the chick's chorio-allantoic membrane to infection with the virus of herpes indicates that the embryonic cells offer a more favorable condition for the growth of some viruses than adult chicken cells. This embryonic tissue would therefore seem to be a promising medium to test the infectiousness of material from those animal diseases which have been proven to be or are supposed to be caused by viruses, but have not yet been transplanted upon an alien host.

The great susceptibility of the chorio-allantoic membrane of chick embryos to infection with vaccine virus is shown by the readiness with which a vaccinal lesion develops and spreads on the membrane, and by the enormous multiplication of virus at the site of inoculation. Bacteria-free virus has now been carried through many generations by passage every three days through the membranes of embryos ranging in age from seven to fifteen days. The infected embryos rarely live longer than four days after inoculation because of the rapid spread of the lesion. At the end of three days a large lesion has developed and this stage has been arbitrarily chosen as preferable for transfer, and for histological and cytological study.

The technique of inoculation is the same as that recently described by Woodruff and Goodpasture,[1] except that we now outline the positions of the membrane in young embryos, 7 to 11 days old, by candling; so that we are sure the window will be cut directly over it. Also the surface of the egg shell is coated with a thin layer of melted paraffine over an area somewhat larger than the proposed window, in order to obviate infection from pieces of shell. After the shell is removed the shell membrane is also coated with paraffine of low melting point so that this membrane may be torn with a sharp pointed instrument on three sides of the window, then folded back and cut with scissors, thus exposing the chorio-allantoic membrane. In this way powdered and fragmented egg shell can not so readily fall upon the exposed serosa and contaminate it.

Bacteria-free vaccine virus obtained from the testis

[1] A. M. Woodruff and E. W. Goodpasture, *Amer. Jour. Path.*, 1931, 7, 209.

of a rabbit has been used to initiate the infection.[2] When transfers are to be made from infected membranes the cover-glass is removed from the window, and the upper portion of the membrane is exposed as widely as possible by breaking off surrounding egg shell with aseptic precautions. The infected membrane is then cut out and placed in a Petri dish containing sterile .9 per cent. saline solution. A small piece of tissue from the thickened and hemorrhagic area is removed with scissors and smears from this are stained by Morosow's method to determine the presence of Paschen bodies.[3] These bodies appear in enormous numbers in the infected membranes although they are difficult to demonstrate in smears from the skin and cornea of chickens infected with vaccinia. Their presence in the smear is diagnostic of infection. Other smears are stained with Loeffler's methylene blue to determine the presence of bacteria. If Paschen bodies are abundant and no bacteria are demonstrable a piece of infected membrane measuring from .5 to 1 mm in diameter is inoculated upon the membrane of each of five or six embryos. We have found twelve day embryos to be perhaps most satisfactory. Pieces of the remaining infected membrane are then inoculated into culture media and others are placed in 50 per cent. glycerol in .9 per cent. saline and in fixatives for histological study.

Sections of infected membranes fixed twenty-four hours in Zenker's solution and stained in a 2 per cent. solution of acid fuchsin for ten to thirty minutes, then counter-stained with Loeffler's methylene blue and differentiated in absolute alcohol, present a most instructive picture. Guarnieri bodies are found in all stages of development, finally filling and replacing almost completely the cytoplasm of the cell. It is to be observed that Guarnieri bodies occur not only in the epithelial cells of ectoderm and endoderm, but in great abundance, reaching a relatively large size, in capillary and venous endothelium, in fibroblasts and possibly in the smooth muscle cells of blood-vessels. It is to be noted that the inclusions develop in great numbers and to a large size before there is any necrosis or cellular infiltration, although inflammatory exudate is abundant in older necrotizing areas. The effect of the infection on capillary endothelium is of interest. The endothelial cells are frequently stimulated to an active multiplication, so as to form small nodules and cords completely obliterating the vascular lumens. Petechial hemorrhages particularly from capillaries are numerous. The ectodermal cells of the membrane are affected first and apparently most severely, although there is often a more widely spread effect upon the mesoderm. Entoderm is affected least.

Smears made from infected membrane frequently show masses of partially dispersed Paschen bodies within the cytoplasm of cells; and pieces of membrane examined in distilled water show round or oval masses in which minute bodies are to be seen in rapid Brownian motion, just like those seen in the inclusions of fowl-pox and *Molluscum contagiosum*. Studies are being made upon the relation of the Paschen bodies to the structure of Guarnieri bodies. The abundance of both these elements and the unusually large size of the latter make this tissue especially adaptable to such an investigation.

Virus passed through eight generations in chick embryos has been applied to the skin of two or three day old chicks after plucking the down. Macroscopic nodules about 1 mm in diameter appear at the site of inoculation within three days. Remaining apparently stationary for two or three days they rapidly recede. Chicks recovered from vaccinia were infected two weeks later with fowl-pox virus and the lesions evoluted exactly like those of fowl-pox in normal chicks. Vaccinia in the chick induces no immunity to fowl-pox.

Our observations suggest that the chick embryo might be used advantageously for cultivating bacteria-free vaccine on a large scale for human vaccination.

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[2] A strain of Levaditi neurovaccine was kindly supplied by Dr. T. M. Rivers.

[3] M. A. Morosow, *Centralbl. f. Bakteriol.*, Pt. I, Orig., 1926, 100, 385.

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